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A New Form of Cooper Hewitt Mercury Vapor Lamp.*

BY F. H. VON KELLER.

Within the last few years such a wealth of information regarding Mercury Vapor apparatus has been published, that a general description of the interesting phenomena appearing in the Mercury Vapor Container would substantially prove a repetition of much that has been well said before. Nevertheless, it seems not out of place to turn attention to one specific technical application of the much discussed principles, embodying some of the most interesting features: a new form of lamp, developed and now commercially employed by the Cooper Hewitt Electric Company of New York To qualify the adjective "new": while the form of this lamp is entirely novel, its operation is based on principles which have previously been employed by the company. This lamp differs from other types of Mercury Vapor lamps principally in its structure and the means for starting the arc in the lamp. Inasmuch, however, as the starting method is a

*Read by title.

factor determining the whole design and layout of a lamp, the one under discussion has assumed a shape differing from other types in more than this one respect.

As well known, the starting of Mercury Vapor lamps offers to the engineer a problem in itself. For, unlike for instance the filament of an Incandescent Lamp, the inert vapor separating the two electrodes of a Mercury Vapor lamp is by no means a conductor of electricity. To render this vapor conducting, such as it is to a very high degree in the running lamp, it is necessary to start and maintain by virtue of the electric current the vaporization of the mercury at the negative electrode.

Thus we encounter an apparent resistance to starting, whose main seat seems to lie in the negative mercury-electrode. To overcome this resistance to starting we can, broadly speaking, employ either one of two methods.

(a) Either break down the negative electrode resistance by means of a relatively high voltage, thereby paving the way for the operating voltage to establish and maintain the flow of current in the lamp,

(b) Or establish current in the negative electrode by breaking its contact to another electrode in the main or in a supplementary circuit.

I. STARTING METHODS.

Assuming that the reader is familiar with the general form of the Mercury Vapor lamp, the following recapitulation will briefly describe a few of the more prominent starting-methods which are being employed in practice:

(a) *Contact-Method.*

The fluid mercury is caused to momentarily form a connecting bridge between the two operating electrodes. When this bridge severs, the flow of current starts. This method is represented by the so-called "Tilting Lamp," where the tube is tilted by hand or automatically by means of a solenoid, thereby causing the mercury to flow from end to end of the tube and to make and break connection between the two operating electrodes. After the current-flow is thus started on the up-tilt of the tube, the same on the down-tilt falls back into its original position by gravity. This

method of starting is by far the simplest in principle, and has proven to be extremely reliable in operation. By this method can be started any tube which will run successfully.* The starting therefore is not sensitive to vacuum conditions. Tilting lamps are widely employed and a representative type is shown in accompanying cut, Figure 1. The lamp-tube of this method in itself is simple, easily manufactured, and easily shipped.

(b) *Filament Method.*

Here the tube itself is stationary, while contact between the negative electrode and the filament is made and broken by means of moving parts placed inside the tube. The filament is a thin carbon rod of high resistance, connecting to and extending from the positive electrode (usually iron, nickel or graphite) down into the vicinity of the negative mercury-electrode. When the voltage is thrown on the lamp, a small current passes from the positive terminal of the tube through the filament to the mercury and the negative terminal. Now this current by magnetizing a solenoid, either raises the filament or lowers the mercury level, thus breaking the contact at the mercury-surface and starting the flow of current between the negative electrode and the filament. The current thus started then climbs along the high resistance filament to the positive electrode, shunting the filament and leaving it to conduct only a negligable amount of current while the lamp is in operation.

Tubes started by this method naturally assume a more complicated form. Their manufacture is delicate and expensive, and the shipping becomes a serious question. Moreover, the starting is sensitive to vacuum conditions prevailing in the tube. Lamps started by this method have not come into the market to any considerable extent, owing undoubtedly to the difficulties inherent to the tube design.

(c) *High Voltage Kick Method.*

Here a comparatively high voltage kick is impressed across the tube-terminals to break down the initial resistance and effect the

*A tube whose vacuum is impaired, but not enough to interfere with successful running, may yet cause difficulty in starting by some methods. Not so, however, when employing the Contact-method.

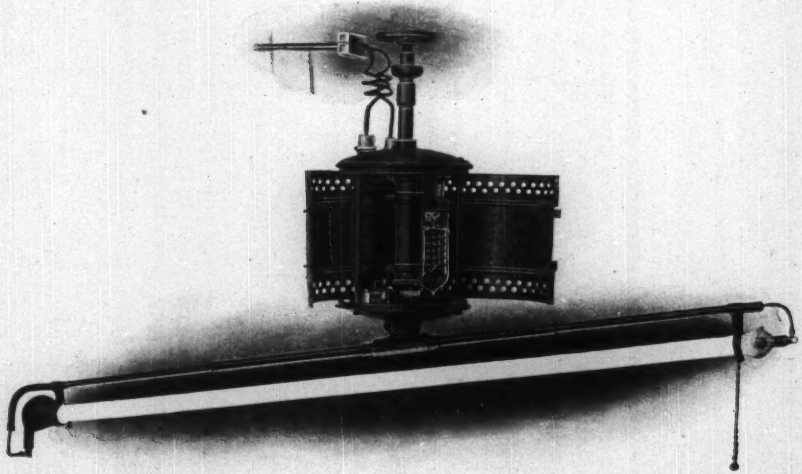


Fig. 1. Tilting Lamp (tube 45 inches long).

starting. As the lamp under consideration employs this method of starting, a more detailed description of the method and the apparatus employed is given in the following:

A quick-break mercury-switch, the so-called "Shifter," is connected in series with the starting resistance across the tube-terminals (See Fig. 2.) When the lamp is switched on, the circuit is completed through the inductance-coil, the Shifter, the starting resistance and the series resistance. The inductance-coil being magnetized by the current, actuates an armature, which

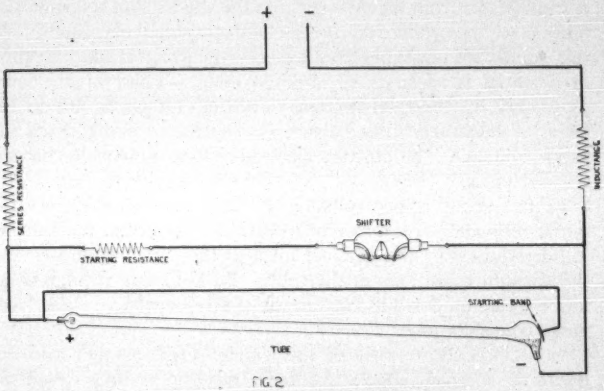


FIG. 2

CONNECTIONS OF AUTOMATIC LAMP

STARTED BY THE HIGH VOLTAGE KICK METHOD

now causes the Shifter to open this starting-circuit. The energy stored in the inductance thereby being forced to find a new discharge-path, now breaks down the initial resistance of the tube, and effects the lighting. The so-called "Starting-band," a metallic coat painted on the outside of the enlarged bulb at the negative end of the lamp, (Condensing Chamber) forms one side of a condenser, the other side of which is the mercury-electrode, the glass serving as dielectric. The Starting-band is connected to the positive terminal and the high voltage which is impressed upon this condenser during the action of the Shifter facilitates the starting.

II. NATURE OF THE INITIAL LAMP RESISTANCE.

We have in the introductory remarks already made reference to the nature of this initial resistance. Therefrom it was apparent that a peculiar excitation of the mercury-electrode was necessary to render the vapor conducting. In all Mercury-Vapor apparatus the negative (mercury) electrode is destined to play a peculiar role. In the running lamp a small white spot of intense brilliancy can usually be observed traveling over the mercury surface in an erratic course and with great rapidity. At this point the current passes from the mercury into the vapor. At this point also takes place the production of the conducting mercury vapor. At this point—we must therefore expect—the greatest concentration of potential is required, to effect starting. Thus, in our lamp 75 to 90% of the total necessary starting-voltage is due to the negative electrode. The balance is required to break down the vapor-column. The positive electrode offers practically no initial resistance.

From 1,000 to 10,000 volts may be necessary to break down the initial resistance of the mercury-electrode, the actual amount being determined by the physical form of the mercury surface and the vacuum conditions in the tube. To hold this voltage at as low a value as possible two means are resorted to in the lamp under consideration:

(a) Upon the outside of the Condensing Chamber and opposite the mercury edge is painted a metallic coating, called the Starting-band (See above.) The same may conveniently extend $\frac{1}{2}$" below and 1" above the inner mercury edge. When the high voltage kick takes place, minute sparks seem to jump from the mercury surface to the glass inside the bulb. As though these sparks had punctured a highly resisting film on the mercury surface, the main current now issues from one or several of these punctures. Thus the result obtained here is of a similar nature as that caused by the contact method, only of course, in this case of less effectiveness than in the Contact—or Filament—methods on account of the less electric energy spent in the discharge.

The Starting-band is a most powerful factor in reducing the initial resistance. The necessary voltage is thereby decreased by approximately 1000 to 3000 volts.

(b) As is well known, mercury lying in a glass vessel will not

form a flat edge and adhere to the glass walls as water does, but the edge will appear round and the mercury will touch the glass walls at a level lower than the actual mercury-surface. Nor will clean mercury readily adhere to the glass. The exciting action taking place at the mercury edge, it appears that the resistance to starting is extremely sensitive to the geometrical form of this edge, in such a way that the usual round edge is productive of a high resistance, whereas a flattened edge will materially reduce the same. Fortunately the presence of a slight amount of amalgam, such as of Fe, Cu, Ag, Pt, Mg, Al (less than .01%) will produce a flat edge of the mercury, without impairing the vacuum of the tube. Incidentally this flat edge will usually take the current during running of the lamp, *i. e.*, the current instead of wandering about the mercury surface will now attach itself to the flat mercury edge, spreading in a thin bright streak over a length of ½ to 1 inch. This fact adds considerably to the stability of the lamp, which is thereby enabled to remain lighted on very much lower currents than when the current is wandering. By flattening the mercury edge or part of it by the addition of an amalgam to the mercury, the initial voltage required may be reduced by several thousand volts.

Besides the factors mentioned, the temperature of the mercury at the time of starting is also a determining factor. Generally speaking, the initial resistance of a hot electrode is less than that of a cold one. The presence of foreign gases in the tube will also effect the initial resistance of the negative electrode in such a way as to lower the same, i. e. the better the vacuum, the higher will be the initial resistance. In normal lamps of the type under discussion (using the Starting-band) the initial resistance of the negative electrode will rarely exceed 3000 volts.

In addition to the negative electrode, the vapor separating the two electrodes also offers a resistance to starting. The same increases with the length of tube and is quantitatively dependent upon the state of vacuum, *i. e.*, the presence of foreign gases, and the temperature of the lamp at the time of starting. The presence of foreign gases will usually increase the vapor resistance.*

*Nevertheless, this starting method is not sensitive to vacuum-conditions. In the presence of foreign gas in the tube the Shifter will "kick" a few times, each time causing a stronger flash in the tube, until there is sufficient mercury-vapor produced to maintain the arc.

III. THE LAMP TUBE.

The lamp tube consists of a glass tube 50″ long and 1″ in diameter (See Fig. 3), the one end of which joins the condensing chamber, the other the positive electrode chamber. The condensing chamber extends into a small cup into which is sealed a platinum wire serving as the negative terminal of the lamp and making connection to the mercury which lies in the condensing chamber. Upon this cup is cemented a terminal-cap connected to the platinum leading-in wire and serving as terminal for the outside connecting wire. The Starting-band painted upon the condensing chamber with aluminum paint makes connection to a suitable post which takes the outside connection. The positive electrode consists of an iron cup attached to a platinum wire, sealed into the glass. The positive end is also provided with a suitable terminal-cap.

The tube is exhausted under a high temperature and during the exhausting the iron electrode is treated, i. e. heated with electric current to a white heat. By this process are removed such gases occluded in the iron, as would be detrimental to the performance and life of the tube.

The tube has a voltage of about 70 to 75 volts across its terminals at the normal operating current of 3.5 amperes.

IV. THE SHIFTER AND THE HIGH VOLTAGE KICK.

The high voltage kick is effected by the action of the Shifter (Fig. 4.) The same consists of a small glass bulb 1¼″ in diameter and 2¼″ long, provided with a groove which partitions off the two puddles of mercury, serving as the two electrodes. To each one of these puddles leads a small platinum wire making connections to a suitable terminal-cap at each end of the Shifter. These caps also serve as pivoting points around which the Shifter revolves. The Shifter is exhausted to a high degree of vacuum similar to the tube.

When the current is thrown on the outfit, the mercury is lying in the bulb beyond the groove and can thus form a continuous bridge connecting the two leading-in wires together and closing the electric circuit. As the Shifter is turned in its pivots around its axis by the action of the magnet-armature, the groove cuts

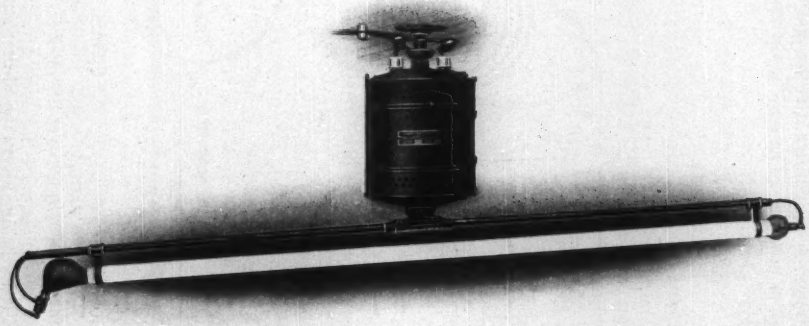


Fig. 3. Automatic lamp, started by voltage-kick method (tube 50 inches long).

into the mercury bridge, dividing the mass of mercury into two separate puddles: the electrical connection is broken.

If it was of advantage in the tube to reduce the initial resistance to a minimum, in the Shifter it is the aim to make this resistance as high as possible. The same is therefore pumped to a

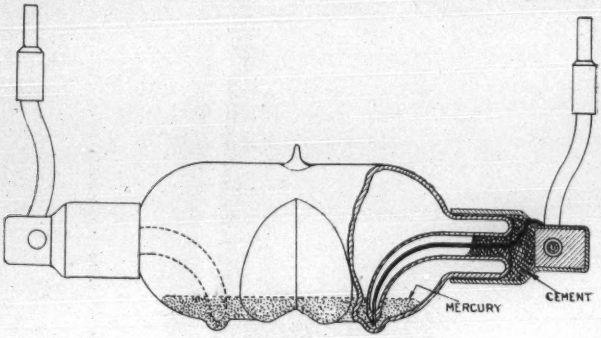
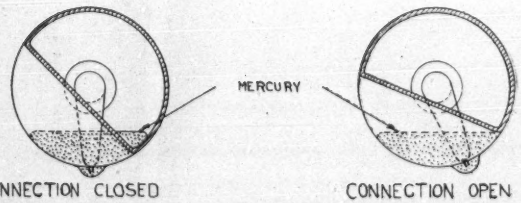


FIG. 4 SHIFTER



very high degree of vacuum and the mercury is kept as clean as possible.

When the mercury bridge severs the Shifter starts and remains running like a small Mercury Vapor lamp, started by the Contact-method. However, the current in the Shifter being limited by the starting-resistance to only 1 ampere, the Shifter will run (i. e. maintain the arc) only about $\frac{1}{4}$ of a second and then go out.

At this instant the initial resistance of the negative electrode of the Shifter re-establishes itself.

Generally speaking, the negative electrode of any Mercury Vapor apparatus will tend to re-establish its initial resistance while running on currents below four amperes. The frequency with which this will occur is a function of the current. To counteract this action in the running Mercury Vapor lamp an inductance is always inserted in the lamp-circuit, which reacts upon these impulses with a high voltage-kick and thus keeps the lamp running. In our lamp the same inductance which serves for starting also insures the stable running of the lamp at 3.5 amperes. This same inductance, however, will sustain our Shifter for only $\frac{1}{4}$ second at the low current of 1 ampere.

When the Shifter-current ceases, there takes place a shifting of the current from the Shifter to the tube. Hence the name "Shifter." To accomplish this shifting it is necessary that at the instant of current-interruption the initial resistance of the Shifter exceeds that of the tube. We see here an instance where the initial resistance of the Shifter with a separation of the electrodes of $\frac{1}{4}$ to $\frac{1}{2}$-inch exceeds that of the tube with a separation of electrodes of 50 inches. This demonstrates how the distance between electrodes (i. e. length of the vapor-column), when compared with the negative electrode, plays a negligable part with respect to the total initial resistance. The difference in initial resistance of tube and Shifter lies of course in the fact that the tube-resistance is artificially held low by Starting-band and flat mercury-edge, whereas that of the Shifter is held high by excellence of vacuum and the use of very clean mercury.

In interrupting the current in the inductance of our lamp, a voltage of about 4000 volts is thrown across the terminals of the tube. This is in practically all cases sufficient to break down the total initial resistance and effect the starting. The operating voltage can now send the normal current through the tube. This current keeps the inductance coils magnetized (See Fig. 2), and thus the Shifter is kept open, i. e. the starting-circuit remains interrupted.

V. AUXILIARY PARTS.

In cut Fig. 5 are shown the auxiliary parts of the lamp under discussion. Connections herein are made as per diagram Fig. 2.

Series- and starting-resistance are both wound upon a porcelain spool, coated with a vitreous enamel. On the series-resistance, (hidden in Fig. 5) connection can be made to either one or two points, thus making the outfit practicable for circuits of widely varying supply voltages. The tube itself

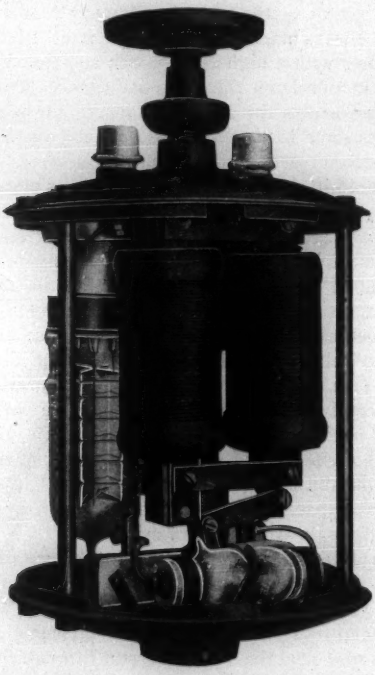


Fig. 5. Auxiliary parts of automatic lamp.

taking only seventy-two volts, the balance of the voltage (with the exception of the drop across the inductance coil) is taken up in the above mentioned series-resistance and in the so-called "Ballast." The latter is a resistance consisting of a fine iron wire and enclosed in a glass bulb containing hydrogen

at a low pressure.* The resistance of this wire rises rapidly with increasing current, due to the increasing value of the temperature-coefficient, as the iron wire approaches red-heat; in such a way that the drop across the Ballast is trebled, while the current increases by about 25%. In spite of the adverse voltage-characteristic of the tube the current is through the action of the Ballast held at a nearly constant value in the neighborhood of 3.5 amperes over a large range of supply-voltage. The lamp is thereby rendered extremely stable and very little sensitive to fluctuating line-voltages, so that the candle power (which is a function of the current) experiences only slight variations on unstable supply-circuits. The function of the inductance in series with the lamp has already been discussed under paragraph IV.

VI. LIGHT, EFFICIENCY AND LIFE.

The light emitted by the tube is of the greenish hue with which the public has become acquainted. While this color excludes the lamp from places where æsthetic considerations in the choice of illuminant are paramount, or where color values must be as true as possible, yet this very color has its virtues not to be underestimated. For the absence of red rays in the spectrum makes this light the least harmful to the eyes among all the illuminants known. Add to this fact the low intrinsic brilliancy of the light (5-6 C. P. per sq. in.), add the great diffusion and absence of shadows under the lamp, (characteristics which are inherent to the tube-form), and it is not surprising to find the Mercury Vapor Lamp holding a distinguished place among illuminants for its very quality of light.

The lamp under discussion gives a light of about 800 C. P. radial to the axis of the tube. Thus the efficiency of this lamp is about $\frac{1}{2}$ Watt per C. P. The lamp is usually provided with a reflector. In the course of the lamp's life the C. P. decreases about 20%, due to the discoloration of the tube.

Fully of as great importance as any of the virtues enumerated stands out the remarkable record which the Mercury Vapor Lamp has established with respect to life. A tube may be said to live as long as its vacuum remains unimpaired. Within the tube,

*The Ballast-wire normally operates at a low red heat. The presence of hydrogen in the bulb from which the air is carefully exhausted, prevents oxidation of the wire and aids the dissipation of heat.

however, no progressive deterioration of vacuum takes place and it is only when the air gains access that a tube will fail. This is usually the result of a crack in the glass-structure, caused by handling or mishandling the tube, by the hammer of the mercury or strains in the glass. Without further analyzing these indefinite factors, a careful compilation of data obtained within the last three years shows an average life of 4000-5000 hours per tube, while tubes of 10,000 hours are by no means unusual. Actually there are a number of tubes in existence whose life exceeds 20,000 hours, and which are still intact.*

This means to the user of the lamp that during 4000-5000 hours any individual outfit requires practically no attention. Thus the cost of maintenance is reduced to a figure unequalled by any other type of lamp in existence.

VII. CONCLUSION.

The lamp described herein is started by essentially the same method as employed by Mr. Peter Cooper Hewitt before the Mercury Vapor Lamp had ever appeared before the public. The first lamps manufactured by the Cooper Hewitt Electric Company, more than five years ago, according to this method were non-automatic, the high voltage kick being produced by the action of a mechanical quick break oil-switch mounted on the wall and operated by hand. The tube was stationary and of a similar construction as the present one, employing the Starting-band. Auxiliary parts were separately mounted on wall or ceiling in the vicinity of the lamp.

The method of starting by tilting has proven entirely satisfactory and has gone largely into use, but as the field of the Mercury Vapor Lamp grew the demand for a simple form or stationary automatic type has made itself more and more felt. As a result of this commercial demand the type herein described has been developed.

*The figures given are based upon performances of Tilting-lamps. The lamp under discussion not being placed upon the market until recently it was impossible to give representative life-data for this lamp. Evidence tends to show, however, that this type will prove even superior with respect to life on account of the total absence of motion in the tube. The moving mercury of the Tilting-lamp is undoubtedly responsible for many of the cracks in the glass-structure.

Diamond Mining.

(Abstract of a lecture delivered before the Franklin Institute, Friday, Nov. 15, 1907.)

By Henry Leffmann.

The diamond has been for many centuries the most precious stone. It owes its prominence to an association of several peculiarities, among which are rarity, hardness and exceptional optical properties. Notwithstanding the comparative ease and certainty with which it can now be distinguished from other stones, it is not sure that in ancient times such distinction was appreciated. It is not unlikely that quartz, zircon, tourmalin and other brilliant crystals were confused with each other and with the diamond. The Greek word "adamas," cognate with our word "diamond," means "unconquerable," and was applied to steel as well as other hard materials. No diamond is known the history of which goes back to pre-Christian times. The oldest was in the mantle of Karl, king of the Franks, better known as Charlemagne, who was crowned Emperor of the Romans in St. Peter's, Rome, on Christmas, A.D. 800. The fact that the territory occupied by the Egyptian and Roman empires does not include important diamond-bearing districts, probably accounts for the gem not appearing prominently in the literature of those nations.

While diamonds may be found in many places, and in many geological formations, the valuable mines are few. For many years India was an important source, but it is interesting to note that Golconda, a name that has been so long closely associated with the gem, is not a mine-locality at all, but a market-town, at which diamonds and other valuable articles were bought and sold. The diamond mines of Southeast Brazil, in the province of Minas Geraes (General mines) have yielded many fine stones, but are now of minor importance, though they have furnished in one year about 40,000 karats (nearly twenty avoirdupois pounds). Diamonds from these older localities have of recent years been termed "old mine stones," and it is probable that most of the gems of this class that now appear in the market are from stocks that have long been in private hands.

Geologists and mineralogists have long been much interested in the genesis of the diamond, and many theories have been put forth. The stone rarely occurs in the place of its formation, hence a study of its surroundings may not assist in solving the problem. Itacolumite has been supposed to be the matrix of the diamond, but this view is not now generally accepted. It is supposed that some light on the formation is thrown by the experiments of Moissan, who found that if iron highly charged with carbon is allowed to cool rapidly under great pressure, minute carbon crystals, having many of the characters of the diamond, are found intermixed with the iron-mass. It has also been supposed that the decomposition of carbon dioxide, or of some hydrocarbons under great pressure, might give rise to the gem, but the conditions in nature do not seem to justify assuming these different actions, or any that have a close analogy to them.

Newton was the first to suggest that the diamond has a relation to organic rather than inorganic matter. He based his opinion on the resemblance between certain optical properties of the gem and those of some hydrocarbons, such as turpentine. Of course, he did not know the formula of any of these, but he knew their organic origin. It seems to me, however, that Newton's view was rather a lucky hit than a logical deduction. In the last decade of the 17th century, about the time that a visitor to Philadelphia was writing to a friend concerning the fine forest that stretched from 4th street to the Schuylkill, two Italian investigators, Averami and Targioni, working under the patronage of the Grand Duke of Tuscany, succeeded in burning a diamond by the aid of a lens.

In 1867, a resident of one of the Boer villages, on the Orange River, South Africa, was attracted by the luster of a stone that a child had found on the river bank. It was ultimately sent to Dr. Atherston, an expert mineralogist, at the English settlement near Cape of Good Hope. He pronounced it a diamond, and fixed a value of $500, which was afterward obtained for it. It weighed 23.5 karats. Further search at the suggestion of the expert failed to discover another diamond until some months had elapsed. The fact that diamonds could be obtained attracted at once, of course, many seekers. For some time the workings were entirely along the banks of the Orange River and its tributaries, especially the Vaal.

After some years of this method of mining, an important discovery was made of a diamond-yielding deposit far from the alluvial soil, which, until then, had been supposed to be exclusively valuable. On the Jaegersfontein farm, in the Orange Free State, southeast of the Vaal River, the frequent occurrence of garnets was noted, and as it had become a belief that garnets are indicative of the diamond, in that part of the world, the overseer of the farm prospected, and a few feet below the surface found a valuable stone. This was the first of the so-called "dry mines," now the feature of South African diamond mining. It is not necessary to give the details of the discovery of the other mines. The most important are in the neighborhood of Kimberly, and are controlled by the De Beers Consolidated Mines, Ltd. Several important mines are not directly controlled by this syndicate. Among these are the Jaegersfontein mine, in the Orange River Colony, about eight miles southeast of Kimberly, and the Transvaal mines, southwest of Pretoria. Even these mines are, however, apparently in a "gentlemen's agreement" with the main company to prevent competition.

The geology of these districts has naturally attracted great attention, but the location is so far out of the line of ordinary travel that but comparatively few have studied it. Passing over the discussions as to the surface geology, now considered by most authorities to be of glacial origin, it is found that the diamond mines are a more or less decomposed mass of rocks filling the craters of volcanoes. These craters are locally termed "pipes." They are at most only a few acres in area, but extend to unknown depths. One of them is now mined at more than two thousand feet below the surface. The mines of the De Beers Company, by far the largest operators, are included within the limits of a parallelogram about eight miles long by six broad, within which five mines are located: DeBeers, Kimberly, Dutoits Pan, Bultfontein, and Wesselton (formerly Premier).

The methods of obtaining diamonds at the mines are entirely different from the old methods, when river gravels were washed by hand. A large amount of intricate machinery has been installed, and some methods have been adopted that have been rendered necessary by the peculiar nature of the product. To understand the principal points it will be necessary to consider the character of the material from which the stone is obtained. The mass

of partly decomposed rock filling the "pipe" is commonly known as "blue ground," from the prevailing color. There is, however, some material termed "yellow ground." The material is sometimes soft enough to break easily, but is usually hard.

When the mines were first opened the work was entirely at the surface, under many claims of small area. The miner simply dug, broke and sifted the earth. This soon led to excavations that interfered with one another and caused accidents by falling earth. Attempt was made by the local government to restrain the excavations, but it was unsuccessful. When a given "pipe" passed under one control, the excavation was simple; the material was taken out regularly. Even this method became unsatisfactory. The deep narrow funnel was liable to accidents and interferences. The present system is largely by shafts sunk in the adjacent hard rocks with lateral galleries at levels of about thirty feet. The following is the order of rock found in the sinking of the side shafts of the De Beers mine: Red soil (decomposed basalt), 20 to 30 feet; black shale, with much free carbon and pyrites, 200 to 300 feet; thin conglomerate, probably glacial, 10 feet; hard amygdaloid (olivin-diabase) 400 feet; quartzite, 700 feet. Quartz porphyry penetrated 1000 feet, and not passed.

The principal minerals found in the blue-ground are olivine, pyroxene, mica and garnet. Serpentine, as a product of alteration, is found in rock fragments.

Although the blue ground is quite hard when mined, it becomes by long weathering friable, and the gems can be obtained by washing. To secure this weathering large storage areas, termed "depositing floors," are provided. One of these, within the De Beers district, is four miles long by half a mile broad, and two others are nearly as large. The floors are surrounded by a fence and guarded, for the material has to lie about a year before it is washed. The washing is conducted by elaborate washing machines, which clear out the looser matter but leave the diamonds mixed with crystals, *e.g.*, garnets and zircons, of little value. For a long while these were sorted out by hand, but it has been discovered that wet diamonds will stick to a greasy cloth, while many other hard minerals will not stick. The separation of the precious stone is, therefore, easily secured by passing the mixture over screens of greasy cloth. The grease is, from time to time, cleaned of diamonds, and is itself occasionally renewed. After

the diamonds are obtained, they must be sorted according to standards of quality. This is done by a few trained workers, who make up packages of different grades and deliver to the business department.

The mining and rough work of the district is mostly done by native (black) labor. Diamond mining differs from all other mining in the ease with which valuable material may be secreted, hence one of the most difficult problems in South Africa has been to prevent the surreptitious removal of the rough stones. A special system has been inaugurated. A native applying for work must sign a contract for a specific time, agreeing to live in an enclosure, called a "compound," until the time has expired. A compound is about four acres in area, and is provided with comfortable living quarters, swimming pool, exercise grounds, medical attendance, and in general, conditions that allow a reasonable degree of comfort. The area is surrounded by a fence of corrugated iron, and overhead screens are placed at the working tables, to prevent the workers throwing stones to confederates outside the grounds. Notwithstanding all these precautions, a considerable loss by theft occurs.

The blue ground is brought to the surface in cars and is estimated by loads, which average 1600 pounds, four-fifths of a short ton. The yield averages about half a karat per load. For the fiscal year, closing about the middle of 1905, the De Beers Company reported:

Mined, 5,128,000 loads (a little over 4,000,000 short tons of blue ground; 2,210,314 karats obtained, a trifle over 1000 pounds. The karat is 3,168 grains. The money value was $24,000,000, so that the rough stone brings on an average $10.50 per karat. It is claimed by the managers that, in spite of their efforts, the loss by theft amounts to over one million dollars a year. The large proportionate yield of the De Beers Company gave it practical control of the diamond market, but as noted above, it now seems that all the other South African sources are syndicated in effect. The United States leads all nations in the importation of diamonds.

Diamond-cutting is a trade but a few centuries old. Amsterdam has long been one of its headquarters, and Jewish workmen most prominent in it. The cutting is much facilitated by the cleavage of the stone, by which, in skilful hands, the form may be

prepared in the rough, but the finishing is done by slow grinding. The standard form of the rough stone is the regular octohedron, often with rounded curved edges. Cubes are rare and are generally modified along the edges by several planes. Tetrahedrons, twinned and other modifications of the first system are found. Colors range from none to black through all the standard shades.

A well-formed octohedron may be cleft by a skilful workman through planes parallel to the base, so as to produce a comparatively broad, flat surface on one side of the base, and a narrow, flat surface on the other, then facets may be cut and a brilliant stone obtained. The cleavage is done by cutting a nick in the face of the stone and striking with a steel edge at the proper angle. The grinding is done by mounting the stone in a mass of fusible metal, which is fastened to a lever-arm so that the face to be ground rests on a plate rotating at high speed and bearing diamond dust. As each facet is finished, the stone must be reset in the fusible metal as to expose a new surface. Diamonds occasionally explode during these operations. This may be due to inclusions of liquid carbon dioxide. Dr. Joseph Leidy reported many years ago to the Academy of Natural Science, the explosion of a diamond in a ring which the wearer was holding in the sun. Diamonds are often in a condition of strain, hence severe treatment may produce structural changes. They are often heated strongly during cutting and sometimes develop cloudiness, which may or may not be removed by polishing. After this a second heating may not produce injury, as the strain has been removed. There is often great loss in cutting. The Koh-i-noor weighed 793 karats when brought to England. It was cut and lost 186.5 karats, and a second cutting lost 102 karats. The average loss is from one-half to three-quarters. Stones are occasionally of unequal hardness at different points. In cutting the Koh-i-noor one face was so hard that six hours' work with the wheel at 2400 r.p.m. produced no visible effect, and a much higher speed had to be used.

The largest diamond so far known was found at the Premier mine, in the Transvaal, in January, 1905. It weighs 3024.75 karats (9582.4 grains, very nearly one pound six ounces). It is an irregular prolate spheroid about four inches long. It is supposed to be a fragment of a much larger stone, but the other portions have not been found.

(Stated meeting held Wednesday, November 20, 1907.)

The Increased Gold Production and Its Effect Upon the Cost of Living.

By F. Lynwood Garrison,

Mining Engineer, Member of the Institute.

Within the past few months the question has been frequently raised, is not the enormous production of gold throughout the world responsible in some degree for the present extraordinary rise in prices of commodities, especially the necessities of life? This increase in the cost of living is apparently not confined to any one country, but is universal, at least in Europe and North America. The feeling seems to be pretty general that gold is being produced in such large quantities as to become cheap, in other words, the ratio between gold and food production has changed. It is possible to obtain approximately accurate figures relating to the gold element of the problem, but reliable statistics of the civilized world's food production do not seem to be available. We can safely assume, however, it is steadily increasing, and on the whole in perhaps no less degree than the growth of population. It will be necessary for us to further assume the ratio between the food supply and population a constant one, that is, one has not substantially gained upon the other during the past decade, although, of course, both have steadily increased.

Within the period from 1896 to 1900, the gold production of the world is given by the German statistician Soetbeer as $1,286,505,000, and in the five years between 1901 and 1905 was $1,611,155,000. Taking the individual years we find the yield in 1896 was $202,251,600; in 1897, $236,073,700, and in 1898, $286,879,700, showing a ratio of increase of approximately 16¾ per cent. between 1896 and 1897, and 21 per cent. between 1897 and 1898. The world's production of 1904 was $347,087,300,

and that for 1905 is officially given as $377,135,100* an increase of approximately 8½ per cent. The estimated production for 1906 is $400,000,000,† an increase of only 6 per cent. It would seem, therefore, that during the years of low prices and more or less business depression, the percentage of increase in gold production is nearly three times as large as in the years of great business expansion and high prices. This substantiates the dicta that within a period of public financial depression gold mining is one of the safest and most profitable occupations. It is evident from the above statistics that the actual increase during the years of low prices was much greater than in those of general prosperity. While obviously this does not show that the accumulation of gold has not affected prices, it does demonstrate that in years of depression the gold output is greatly accelerated. The question hence arises, has the amassing of gold been greater than the demands of increased business? It is difficult to see how it could, since the larger the volume of business the greater demand there must be for a circulating medium of exchange.

Some persons appear to erroneously consider that gold is an actual standard of value. It is of course in a sense an arbitrary one, the real standard being that of labor, the unit of which must be the amount of work a man can do in a given period, or, to use the words of Thoreau, "the cost of a thing is the amount of what I call life which is required to be exchanged for it." To support this life we must have food and when that increases in cost the price of labor must necessarily rise in like proportion.

Assuming that the general condition of trade throughout the world does not affect and is not influenced by the volume of gold production, the question arises, will the increase of the gold output keep pace with the demands for that precious metal, both for use as currency and consumption in the arts. Reviewing the production of gold in the United States in the year 1906, which was $94,373,800, we find that there has been a net increase over the year 1905 of $6,193,100, nearly all of which is credited to Alaska. The older gold-producing States of California, Montana, South Dakota, and Washington show a decreased production of approximately $300,000 each, and Colorado, Utah, and

*Report of Director of U. S. Mint for 1905, p. 37.

†Personal letter from Acting Director of U. S. Mint, October 22, 1907.

Idaho a small decrease, Arizona a slight increase and Alaska and Nevada an enormous advance. The great gain in production of the vast and virgin territory of Alaska was perhaps to be expected, but the increased production of Nevada from $5,359,100 in 1905 to $9,278,600 in 1906 was surprising, and is chiefly attributable to the remarkable discoveries of rich gold and silver ores in the Tonopah and Goldfield districts. It is doubtful, however, if this ratio of increase or even the same rate of production in Nevada can be maintained, since it is believed by well informed mining men that the yield of the Tonopah district has about reached its limit, as several of its best mines are showing signs of exhaustion. This is what might be expected from the injudicious manner in which some of these fine properties have been managed, or rather mismanaged.

In California hydraulic mining is not holding its own, and shows signs of dying out, whilst the dredging industry is increasing and has abundantly demonstrated its profitableness in favorable localities. In fact, it is safe to say that this form of gold washing and recovery is in its incipiency, and as it grows and develops, is certain to increase the gold production in many districts, thus materially assisting in maintaining a steady yield from the older producing areas. The quartz gold production in California has not substantially increased, but perhaps may do so as successful methods are developed for treating very lean ores. The writer cannot account for the falling off in the production of Colorado in 1906, as the labor troubles which so seriously affected the mining industry of that State appear to have been fairly well settled. It may be, that owing to the agitation produced by these disorders, capital has been scared away, and comparatively few new mining enterprises were inaugurated in Colorado. In Montana a large proportion of the gold production is from copper ores, and as this yield has steadily increased, the falling off in the gold output must be ascribed to other causes; in fact, since 1904 there has been a steady increase in copper and a marked decrease in gold production. In South Dakota the improvements and economies at the great Homestake mine seem to have failed to hold the gold production to a steady figure, since there has been a decrease of $110,700 between 1904 and 1905, and of $309,000 between 1905 and 1906. In Utah for 1906 over half of the $5,130,900 of gold output was from copper ores. In Idaho the gold

production is chiefly from placer mining, and showed a decrease between 1905 and 1906 of $39,900. Except in Alaska there has been a decided falling off of the yields from placer or gravel mining as far as the United States is concerned. This is what might be expected, for placer and gravel washing is always the first mining system adopted when a new gold producing territory is opened up. After such alluvial deposits are exhxausted, the miner seeks for "quartz" gold or ledges, generally with unsatisfactory results, for such men are usually inexperienced in milling as well as under-ground mining. On the whole, it would appear that with the exception of Alaska placer or alluvial gold mining in the United States as an industry is dying out, and is giving way to dredging. The increased production of gold seems to be largely due to the copper ores, and to the exceptionally rich though somewhat erratic gold and silver deposits of central and southern Nevada. In this State it is doubtful if the present rate of production can be maintained, unless new gold deposits are discovered, and the expected large production of copper ores in the Ely district yields abundantly of the precious metals. While of course it would be unsafe to assert that the present ratio of gold production in the United States proper (not including Alaska) cannot be maintained, it is nevertheless difficult to see where the gold is to come from. Of Alaska we have reason to expect great things, for this vast territory is but partly explored, even in a geographical sense, but doubtless it also has its limitations.

Turning now to other parts of the world, we find that the gold yield of the Transvaal has about reached its maximum, since the best authorities appear to agree that it will from now on steadily decrease. The yield of this justly celebrated district is enormous, and is now considerably over $100,000,000 per year. Other sections of South Africa are not very promising with the possible exception of Rhodesia, which in 1905 yielded $7,224,605. The gold production of Mexico is relatively not large, but there is reason to expect it will steadily increase. The same may be said of the Central American States and South America, which probably contain to-day the largest unexplored and undeveloped sections of the habitable earth.

In Europe, Russia is the only great gold producing country. The yield of European Russia and Siberia in 1904 being 37,321

kilos of gold, and in 1905, 33,541, equivalent to $22,251,587, the decrease in the year being ascribed to the disturbed political conditions of that country.

The conclusion is therefore unavoidable that the world's gold production has not reached an abnormal or unhealthy proportion when compared with the enormously increased commercial activities of the times. On the contrary, if anything, we need more gold, for business seems to have outgrown the supply of circulating medium, that is, coined money or currency. Gold is certainly not cheaper, and as some of the chief present sources of supply are exhibiting indubitable signs of exhaustion, it is not likely to become so. It is therefore evident that if the present rate of increase is to be maintained we must soon call upon the comparatively undeveloped fields of Siberia, Central and South America, and perhaps parts of Africa, although the prospects for gold in the latter country are not encouraging.

Continuing this analysis further, we find it is evident the quantity of gold derived from copper ores must be quite large. In the statistics for Arizona and California, this particular phase of the yield seems to be given only in terms of silver, that is, the amount of gold thus derived is not specifically stated. In Montana, however, $1,434,935 of the total $4,889,233 of gold produced by that State in 1905 came from the copper ores; that is, about 29 per cent. of the gold yield of the State was thus obtained, and in 1906 it was probably much larger. New Mexico, for 1905, gave $76,455, or about 29 per cent., from copper ores, whilst in Oregon it was only 1½ per cent. Within the old gold producing States it seems we will in the future have to look to the dredging industry and the copper ores for the increase of gold production, if, in fact, we are not obliged to depend upon these sources to maintain the present amount and prevent a steady decline. The total yield of gold as an incident of the copper industry is evidently an important element, although the precious metals thus derived are proportionately very small and may be regarded as a by-product, since copper ores do not usually contain more than one or two dollars of gold and silver per ton, the ratio being about one part of gold to three or four of silver. The yield of these metals from this source will therefore

depend upon the production of copper, which in turn is regulated by the price of that metal.

From a careful consideration of the whole subject, it is evident the gold production of the United States (not including Alaska) is not likely to continue exhibiting a substantial increase, if in fact it can maintain its present rate. There are doubtless many gold deposits of one kind or another in the United States that could be made to pay enormously in a country like China, where there is an abundance of cheap, and for the purpose, efficient labor, but in this country of high prices and extravagant living, such deposits would probably not yield a new dollar for an old one, even with the best of our so-called and sometimes over-rated labor-saving appliances. I believe it is an error to suppose modern mining and metallurgical methods can or will materially modify the gold production of the United States, although of course in some, and perhaps quite a number of instances, the yield of gold can in this way be increased, but as a factor of the whole question these modern innovations may be said to be comparatively unimportant.

Gold is not, as commonly supposed, a rare metal, indeed it is quite a common one in the crust of the earth, but it is exceedingly widely distributed and finely disseminated. It probably occurs in appreciable, though minute quantities throughout many, if not most of the Tertiary eruptive rocks that compose the vast chain of mountains extending from Alaska on the north to Tierra del Fuego on the south. The gravels underlying Philadelphia contain it, and the iridescent though dishonest scheme of Jernegan was based upon the substantial fact that gold does occur in sea water. The forces of Nature through millions of years have concentrated some of this gold in certain places favorable to its accumulation. By common process of erosion the particles of gold gather in stream beds, sea beaches and other alluvial and fluvial deposits. Through its solution in the circulating "waters under the earth" gold is carried from place to place in the rocks and precipitated in favorable locations, usually along with other metals. These latter phenomena are very obscure, but are slowly yielding to scientific study and research. In general, it may be said that the processes of metallic accumulation within the rocks are essentially superficial in the sense that they are probably going on at no great distance below the surface. Metallic veins and deposits do not usually increase in size or richness with great depth,

although there are of course some mines that can be worked about as far below the surface as our present mechanical limitations will admit.

In conclusion, it is difficult to see how the production of gold throughout the world can possibly continue to increase in the same rate as within the past few years, especially in the face of the continued increase in the price of labor, or to put it in another way, the cost of living. In the United States, especially in the manufacturing States like Pennsylvania, the land has been too frequently deserted by its tillers to labor in the factory, with a consequent increase in the cost of food and an absurdly high protective tariff has stimulated the manufacturing interests as alcohol will an individual, creating a brief sense of exhilaration followed by its distressing but inevitable reaction. Extravagance saps the wholesomeness of family life, and if continued is certain to destroy the nation.

GRANITE IN MAINE.

During the summer of 1905, Mr. T. Nelson Dale, of the United States Geological Survey, visited all the important granite quarries in Maine. The results of this work are soon to be presented in a bulletin entitled "The Granites of Maine," to which Dr. George Otis Smith has contributed an introductory chapter and map showing the geographic and general geologic relations of the granites in that State. The bulletin will also include the statistics of the granite production in Maine for 1905, prepared by Miss A. T. Coons.

The number of quarries and prospects visited, including those of "black granite" for monumental use, amounted to 129. The capital invested in the entire Maine granite industry in 1905 amounted to about $3,500,000. This estimate is based upon fair valuations of the quarries themselves, of the plants, and of the amount of "working capital" that is required to carry on the present business.

The report is designed to be helpful to those who are engaged in quarrying and working granite, as well as to architects, contractors, and dealers in monumental stone, and it will also make known to geologists the results of such scientific observations as were made in the course of the work. In order to accomplish these various purposes it has been divided into two parts—a scientific and an economic part.

The first is practically a brief text-book on granite in general, illustrated by the quarries of Maine and written as far as has been possible in untechnical, granite language, so as to be intelligible to working and business men. This part treats of the origin, mineralogical and chemical composition, texture, structure, physical properties, and classification of

granite and "black granites." Under the heading "Structure," the nature and origin of sheets, rift, grain, flow structure, joints, headings, and faults are considered. Dikes, veins, "knots," geodes, inclusions, and contracts are described and discussed, as well as the discoloration and decomposition of granite.

In the economic part the various tests of granite, the adaptation of the stone to different uses, and the methods of granite quarrying are first considered. An economic classification of Maine granites based upon visual characteristics is next given, and then follow the descriptions of the quarries and their products, the matter here being arranged by counties in alphabetic order. These descriptions follow a uniform method, taking up in succession (1) the name and location of quarry, name and address of operator and superintendent; (2) the granite, including its description in the rough and under the microscope, together with the results of any tests and analysis; (3) the quarry, its dimensions, drainage, and water supply; (4) the stripping and rock structure; (5) the plant, including an enumeration of all machines and pneumatic tools, to show its capacity; (6) the means of transportation; (7) labor, both of men and animals; (8) product, its uses and market, together with the names and location of buildings or monuments containing the stone.

At the end of the report is a bibliography on the economic geology of granite and a glossary of such scientific terms as were unavoidably used and also of current quarry terms. The report includes fourteen plates illustrating various features of scientific or economic interest in the quarries or their product and forty-one text figures. Most of these text figures are diagrams showing the course of joints, headings, and dikes at the quarries, but others illustrate "rift," sheet structure, "sap," or the use of explosives, or show the location of individual quarries at the industrial centers. The situation of these centers is indicated by symbols on the geological map.

WHY MONEY IS SCARCE.

Many theories are advanced as to the principal causes of the scarcity of funds that has existed for a long time, says the *Wall Street Summary*, A banker in this city, who has made a close study of the question, and who has been extremely conservative for many months, principally because of the monetary situation, says that he believes that a large amount of money is in the hands of laborers, artisans and others whose wages have been very materially increased within recent years. He believes that people of this class are carrying about a much larger amount of money than ever before. Others, who hold this same theory, point to the fact that the newly-arrived foreign element is receiving much higher wages than was ever paid to that class of people until a few years ago, and that many of them hardly know what a savings bank is, and consequently are simply hoarding their savings. It is believed that this situation is a very important factor in the money market.—*Iron Age.*

Section of Photography and Microscopy.

(Stated meeting held Thursday, November 7, 1907.)

A Color Screen Color Meter.*

By Frederick E. Ives.

The nearest approach to a universal color meter which is now commercially exploited for use in the arts and industries, employs arbitrary standards and scales, and different sets of standards for different arts, trades and industries. The numerical readings are of a complicated character, with an indefinite qualification of "brighter than standards" or "duller than standards," and the percentage values are quite unreliable because of the introduction of an indefinite number of reflecting surfaces.

By an adaptation of the fundamental principle of the Maxwell "color box," substituting a special photographic diffraction grating for the prisms in Maxwell's device, and making the instrument "direct vision" and compact, with slit adjustments controlled from a point near the eye, I made it possible without further complication to match, measure and record all such colors as can be found in the arts and industries. My diffraction color meter was demonstrated here on April 25th of this year, and the paper published in the *Journal* of the Institute in July.

I stated in my paper that some difficulty had been experienced in perfecting mechanism for giving accurate percentage readings of the opening of the three narrow and unequal slits. This was successfully accomplished, but there was reason to think that the correct adjustments might not always be maintained, and that users of the instruments might sometimes neglect to verify the adjustments before taking measurements. Although this, being a purely mechanical detail of the instrument, might very probably be satisfactorily perfected by a mechanical expert, it seemed to me to be worth while, before going any further with it, to see how nearly I could come to the same results by substituting three com-

*Read by title.

paratively large rectangular openings covered by special color screens for the slits and grating, and mixing the colors by an optical device, thus permitting of the use of much less delicate "slit" mechanism, and at the same time making it impossible to use wrong standards by shift in the spectrum.

I finally succeeded in obtaining practically the same results as with the diffraction color meter, without material alteration of size, general appearance, method of application or facility of adjustments, and with the further advantage that a much wider eye slit is used and the light is of exactly the same color at both edges of it.

Although this instrument differs very materially from its predecessor, it will be seen later that it represents a further evolution of the same idea. The two most novel elements in this device are, (1) a nearly juxtaposed set of three rectangular color screens which transmit respectively and exclusively the spectrum rays A to C 1/4 D (fundamentally pure red) a remarkably narrow and well defined band in the green with maximum at *b* (wave length 517) and from F 1/2 G to H (blue violet), and (2) a revolving wheel of convex lenses which optically mixes these colors to the eye, in the field of the instrument. For comparison purposes, a laterally placed clear aperture is provided, transmitting light which is bent into the axis over one half of the field by a wedge prism and spread across it by the optical mixing wheel in the same manner as the three colors.

It would have been impossible to produce a satisfactory device of this character but for the discovery, as the result of much experiment directed to that end, of means for producing a permanent green color screen transmitting very freely but exclusively the spectrum rays of a narrow band over *b* in the spectrum. The purest green glasses transmit a diffuse band of spectrum green very many times too wide, and therefore far too impure to compete with the narrow band taken from the spectrum in the Maxwell color box or the diffraction color meter. The green of this new screen is of such definite hue and purity that it serves the purpose practically as well as a sharp band taken out of the pure spectrum by prism or grating. It is also a permanent color screen, showing no trace of change after long exposure to summer sunlight, and the color is not changeable by adjustment, like the changes which would result from any accidental shift in

spectroscopic device. Of course, the red and blue screens also possess these merits, but their production in my hands involved no extended experiment or special difficulty.

Maxwell measured the colors of the prismatic spectrum in terms of red at C, 1/4 D, the green at E, and the blue at F 1/2 G. Later authorities have generally chosen a green at *b*, or even a little further towards F, and in some cases a blue also nearer the F than Maxwell's. The green at E will not mix with the blue at F 1/2 G to absolutely match the spectrum at F, and the green at *b* will not mix with the red to absolutely match the spectrum at D. It is necessary, in both cases, to add a trace of white to the pure spectrum color in order to match it with the mixture. The green at *b* will give better average values throughout the spectrum than the green at E, and a blue nearer to G is necessary to match purples consisting of fundamentally pure red mixed with spectrum indigo-violet.

The colors which I have adopted have as nearly as possible the hue values of the spectrum at C, *b* and G, and that this triad is the best obtainable for a color meter to measure up all such colors as are to be met with in the arts and industries is absolutely proved by experiment on such colors.

A Maxwell color box, using Maxwell's primaries, failed on deep aniline violets which the screen color meter would match, and by reason of the yellower hue of Maxwell's green, it was no better for peacock blues than the screen meter; both would match all such peacock blues as are to be found in the arts and industries, with a difference only of percentage readings. Orange hues containing no trace of white cannot be exactly matched by mixing the *b* screen green with the red, but the purest of such colors in fabrics, etc., reflect enough white light superficially to make a perfect match possible.

By means of this color meter, every color to be found in the arts and industries can be quickly and accurately matched, measured in terms of three definite spectrum hues, recorded by three numbers, and reproduced for observation or matching at any time by simply setting the instrument to the recorded number and directing it to a background of standard white. It is not even necessary to introduce the letters R, G, B in the record, since if the numbers be given in the same order, the first is always to be taken as red, and the last as blue.

PHOSPHATE ROCK IN THE WEST.

The discovery of important phosphate deposits over a considerable area in southeastern Idaho, southwestern Wyoming, and northeastern Utah has opened up a new industry in the West. The future of the industry is, however, shrouded in uncertainty as it is largely dependent on the granting of such rates by the railroads as will enable the manufactured product or raw material to be sold at a profit in Australia, Honolulu, Japan, and the Middle States, the home market on the Pacific Coast not being at present extensive enough to warrant large development. This phase of the subject is recognized by Messrs. F. B. Weeks and W. F. Ferrier of the United States Geological Survey, who have investigated these deposits and prepared an article about them for the Survey's forthcoming annual volume, "Contributions to Economic Geology, 1906."

Prospecting has been carried on at a number of widely-separated localities. The strike of the beds follows the general northwest-southeast trend of the ranges along which they outcrop. In Idaho the beds outcrop along the Preuss Range, extending from the line of Bannock and Bear Lake counties in a southeasterly direction along its west face. A probable southern extension of these beds near the Idaho-Utah line is found on the plateau east of the Bear Lake, where the overlap of upper Mesozoic sediments has been eroded. East of the Preuss Range, in the Sublette Range, in Wyoming, are similar beds which follow the southerly trend of this range to Smiths Fork. The deposits are found in oolitic beds of the upper Carboniferous rocks and contain a variable percentage of P_2O_5.

This general region is drained by Bear River and its tributaries. The Oregon Short Line Railroad follows the valley of the Bear River and affords the only means of transportation to market. At present those beds which can be developed at the least cost and which lie nearer the railroad shipping points are worked. In Utah the phosphate series has been found some distance south of Bear Lake, in the vicinity of Woodruff. The beds also outcrop in Weber Canyon, about 1½ miles below Croydon, and in some of the side canyons. None of these beds are at present worked. The Union Pacific Railroad, which follows the course of Weber River, will make possible a rapid development in this region.

Beds of good grade, but too thin to be profitably worked, have been observed at other points in these States and also in Nevada. It is highly probable that further exploration will show that these oolitic phosphate beds have still wider distribution.

The phosphate series consists of alternating layers of black or brown phosphate material, shale, and hard blue or gray compact limestone. The limestones are in the main very fossiliferous. The phosphate series is in places about ninety feet thick. The beds vary in thickness from a few inches to about ten feet, but wherever they are of this extreme width they are broken by thin layers of shaly material poorer in P_2O_5. The main phosphate bed is from five to six feet thick, and is almost entirely oolitic in structure and high in P_2O_5. All the sections that have been examined show one, and some of them two beds which are of commercial value.

Mechanical and Engineering Section.

(Stated meeting held Thursday, October 31st, 1907.)

The Pitometer.

By Edward S. Cole.

Modern methods of economy have made their way into our conservative city water departments, and a desire to know what becomes of a costly water supply in its dark and hidden path from source to consumer has been aroused, so that a full accounting is now expected of the distribution engineer as well as of the official who collects the water rents.

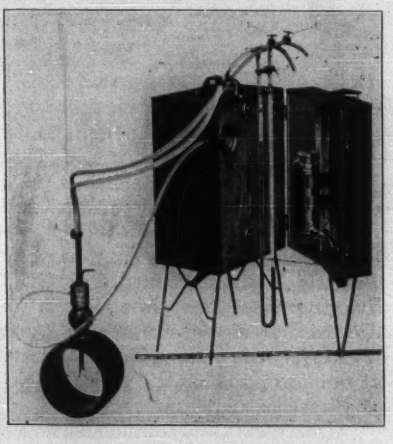
In attempting to account for his product the water works man has always been at a disadvantage because several feet of earth and costly paving cover the heavy iron pipes in which a water supply is distributed. To dig down and "cut in" one of the older types of meters is a very costly and difficult undertaking, so much so that important information has lain buried within these mains and much loss of revenue and of outlay has resulted.

Simple and portable means for recording the flow in pipes have been sorely needed to check the underground losses and waste which have grown to alarming proportions in nearly all American cities, and it has been because of this lack of means that our distribution systems, which are the most costly and vital part of a water works plant, consisting as they do of a vast gridiron of cast-iron mains, aggregating hundreds of miles and costing millions of dollars in any large city, have received less scientific attention than the more conspicuous features of a water works property. Thus while *filtration* has benefitted by the wonderful development of recent sanitary science, and a century of steam engineering has produced at last the high duty pumping engine,

but comparatively little has been done to improve the equally important pipe system by which water is distributed.

For the same cause costly extensions of mains have been left largely to guess-work, and much money thus thrown away for lack of the data on which their proper design depends.

Now, by use of the portable pitometer, measurements may be had at any point on such a system by simply making a tap and placing a one-inch service cock in the main, and such measurements may be repeated as often as desired at any time, by day or night, in winter or summer.



The Photo-Pitometer.

The development of the pitometer was taken up by the writer in 1895, under the direction of John A. Cole, C.E., in the hope of making use of the Pitot tube as a waste-meter at Terre Haute, Indiana, where an extensive examination of water consumption was being carried on. After much costly experimenting, suggested by a crude sketch contained in Prof. R. C. Carpenter's "Experimental Engineering," the instrument proved to be accurate and efficient, and since the addition of a photo-recorder, has been adopted on important tests in many of our largest cities.

Its fundamental principle was discovered by the French engineer, Pitot, about the year 1732, and later improved by D'Arcy for use in open channels, but the application to water-mains under pressure was developed only during recent years. The photo-record-

The "rod meter" and "street connection."

ing pitometer may now, however, be classed among our most useful and accurate engineering instruments.

Prior to 1895, when my work began, there seemed to be very little published data available to guide an investigator in this line.

It afterward appeared that both Mr. John R. Freeman, at Lawrence, Mass., and the late Henry Fladd, at St. Louis, had worked quite successfully toward a development of the Pitot tube in this direction. More recent contributions by Williams, Hubbel and Fenkel at Detroit; and Gregory and White, at Tulane University, have been made.

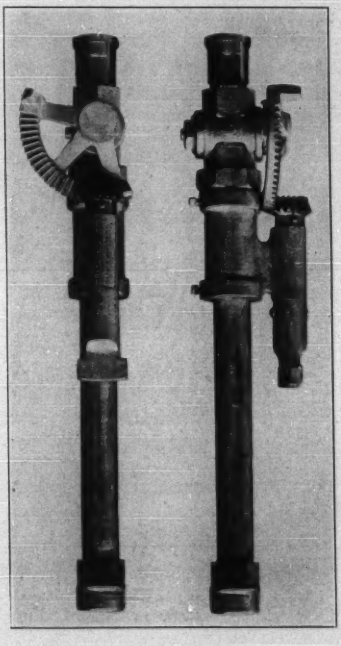
The pitometer is primarily a rate meter, depending as it does upon the velocity of the water within the main. It does not directly indicate the total discharge in cubic feet in a given time, as do ordinary meters, but this elimination of the time element proves to be valuable in a waste meter, for by the changes in rate we are able to study the effect of closing valves and service cocks in an investigation of underground systems.

The instrument consists of two small tubes bent at their lower ends, with carefully formed orifices, held in a suitable cap, which screws upon a standard 1" corporation cock, through which the tubes may readily be introduced into any main and as easily withdrawn. The rod meter is the most recent development of the instrument by which the slender tubes are enclosed in an oval sheath which enables the meter to be introduced into the main from the surface of a city street through a "street connection" which is permanently set upon the main. Wherever street connections are placed they are always available for use, and through them by means of the portable rod meter the flow in the main can at any time be ascertained.

Heavy cloth insertion rubber tubing connects the orifice tubes with a long glass manometer, or U-tube, and blow-off cocks are provided to remove air from the instrument. The U-tube is half filled with a mixture of carbon tetrachloride and gasoline, having a specific gravity of 1.25, and when in use the water from the pipe fills all the remaining space in the U-tube and connections. The deflection, by virtue of the differential action of the water and the slightly heavier insoluble liquid, is just four times that due to the actual difference of water head on the orifices produced by the flowing stream. The current impinges directly on one orifice, but the other is turned down stream, and gives something less than the static head within the main, thus increasing the difference of pressure produced. This difference is then multiplied in the U-tube, the result being that even a low velocity within the pipe produces a readable deflection. Without this effect the simple

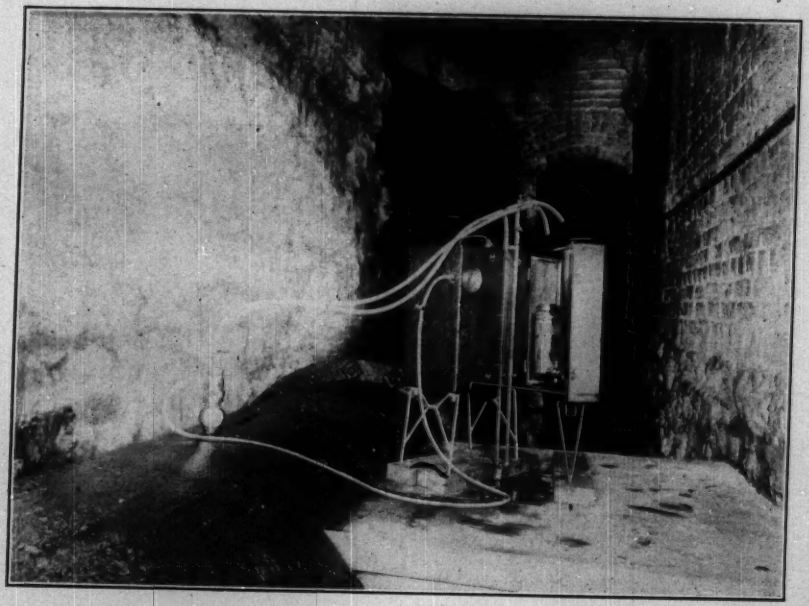
Pitot tube would hardly indicate a velocity less than one foot per second, while the pitometer is reliable at velocities as low as six inches per second. At ordinary velocities the U-tube deflections may run up to twenty-four inches, and therefore need not be read with any great nicety.

The photo-recorder consists of a portable box in which a drum



The "street connection."

carrying Velox or Azo paper revolves before a fine vertical slit just in front of which is locked one leg of the U-tube in such a position that the rays of light from an oil lamp will be partly intercepted on their way through the colored liquid in the lower half on the manometer. As the liquid rises and falls with the velocity in the pipe, it will record on the sensitized paper a line or



The pitometer at work upon a 16-inch main.

band of shade whose ordinates vary according to the well-known formula:

$$V = c\sqrt{2gh},$$

in which h is one-quarter of the U-tube deflection in feet, or half of the recorded ordinate on the paper. A twelve-hour photographic record is 18 inches long and 10 inches high. Autographic horizontal lines are formed by notches in the drum slit, spaced so as to correct for the angularity of the light and enable the true deflection to be readily taken from the diagram at any point.

An autographic record or variation in static pressure is superimposed upon the flow diagram by means of a suitably connected gauge and movable finger, which intercepts the light passing through the U-tube and slot. This pressure record is of great value in the interpretation of any sudden change in the rate of flow, for by its aid we may decide whether the observed variation is caused by a corresponding difference in pump pressure, as in "direct systems," or by the change in rate of draught within the district under investigation. Thus the detection of waste is facilitated.

The accuracy of the pitometer has been established by many weir tests, and also by calibration in open channels, where the absolute velocities indicated by the instrument are compared with float measurements.

The calibration constant c of the orifices has thus been experimentally determined to be .80 in our formula.

We have, then, $V = .8\sqrt{\frac{2\ gd}{4}} = 3.212\sqrt{d}$,

in which d is the U-tube deflection in feet. The actual velocity of the water is indicated in this way wherever the orifices may be placed within a pipe, and by completely "traversing" a given pipe section on two diameters, we may readily integrate the flow by the "ring method," compute the mean velocity, and find its ratio to the maximum at some one rate of flow.

This ratio once determined for a given pipe holds good at all velocities. The orifices are then permanently set to give the center or maximum velocity within the pipe, reading off the mean velocity and the discharge from a table prepared for the par-

ticular size of pipe and velocity ratio. This method leaves nothing uncertain. The mean velocity computed from a traverse of a pipe with the pitometer has been checked by careful weir measurement of the flow in pipes from four inches to seventy-two inches in diameter, indicating that with careful use the discharge in pipes may be determined by the pitometer within two or three per cent. of the truth, an accuracy which is highly satisfactory for the solution of practical hydraulic problems.

Such being the nature and form of the instrument itself, it remains to consider its practical utility and the several ways in which it has been applied to the problems which are presented by a modern water works plant in a rapidly growing city.

These naturally fall under two leading lines of investigation, each of which is of incalculable commercial importance, and in each of which the pitometer affords unique and economical methods. These are, first, the survey of underground pipe systems for the purpose of locating all uses and waste of water, incidentally ascertaining the condition of water mains, stop valves, and house services; and second, the supervision of pumps by means of which any loss of action or imperfection in work is revealed.

It is well to remember that water delivered under pressure through pipes is by no means a cheap product, and a few figures may help us to bear this in mind.

The actual cost of supplying one million gallons of water in many of our American works varies widely from about $20.00 in some of our large cities to $300.00 or more in the case of some small plants. The average for twenty-two cities of moderate size reported to the New England Water Works Association for 1904, was about $92.00 per million gallons for operating expenses and interest on bonds. In Chicago, where there is no filtration, the cost of water has been estimated at $19.00 per million gallons on the same basis. There, for example, the distribution system has two thousand miles of mains from four to forty-eight inches in diameter, valued at $16,000,000, or one half the cost of the whole Chicago water works system, which is placed at $32,000,000.

With the growing demand for pure water supplies, involving vast expenditures for filtration works, the cost of water is increasing. For example, the city of Philadelphia is completing filters to cost over $30,000,000, and the necessity of reducing waste here is obvious.

Waste of water is really *the* great evil in our American water works systems, and its effect upon city finances is twofold: First, in the desperate attempt to fill the "sieve," which our leaky systems resemble, large appropriations are needed year by year to increase the pumping capacity; and second, the pipe system needs continual re-enforcement to enable it to maintain adequate fire service over and above the useless losses which drain its capacity.

Broadly speaking, waste is not the generous, or even lavish use of water by consumers, but is rather the willful and careless misuse, by which streams run continually from faulty house fixtures and from leaky underground pipes. Water works losses include also the very serious problem of illegal *use* of water by large-meter consumers, through "by-passes," which rob the city of much needed revenue. Useless waste may amount to half the total supply of a city, or even more. For example, in his report on water measurements, Mr. Dexter Brackett, C.E., concludes that half the total supply of the Metropolitan District is wasted and obviously a waste of one-half is a serious matter.

In a water waste investigation a city is divided into large districts, closing all the main gates but one, placing a recording pitometer on the inlet to the district, and keeping a record of the inflow. This total use in connection with the district population and the amount registered by the private meters will give a good idea of the wastefulness of the section, taken as a whole, the rate of night use being most significant. In case the district shows a reasonable rate it may be passed by, thereby saving the expense and trouble of house to house inspection.

If, on the other hand, an excessive consumption per capita is indicated, the next step is to analyze the supply by streets, using the pitometer to record the "drop" in flow as valves are closed one after another. All streets do not waste water at the same rate per tap, and for this reason it is easier to pick out an unusual flow. When the night waste has been localized within a few blocks this smaller section is enclosed by itself and supplied through its own waste meter.

Then, if necessary, the curb cocks are closed one after another at night, the waste meter at the same time continuously recording the rate of flow, so that when a house is reached which has a leaky service pipe or fixture the pitometer on the main, on closing the main cock, will record a "drop," which is the rate of waste.

In this way a record showing the condition of every house on the street is obtained and waste is located, which can further be defined by house to house inspections. The waste meter record not only locates the loss on certain premises, but measures it.

This American method by the use of the pitometer is the development of the long-established Deacon system, which, although still very much depended upon in England, has not proved popular in this country, although for several years it was used in Boston with success.

Every large city should organize its own permanent depart-

A portable "shelter box" in use at Fairmount Park, Philadelphia.

ment of the systematic detection of waste according to some such plan as has been outlined, and in Washington, D. C., Pittsburg, and Chicago this has been done.

The work calls for the intelligent and skilful supervision of an engineer, and must be persistently followed up for years if need be, to secure the final results. The time required to traverse a square mile depends on the number of waste meters employed, and upon the physical condition of the pipe system. Several districts may be inspected at one time under the direction of one

competent head. Experience has amply proved the value of such work for its results are felt at once, and the cost may be repaid out of savings as the investigation proceeds.

The increase of income and the saving of expenditure for new pumps and mains will net millions of dollars to taxpayers. Purification works which will sooner or later be demanded in many of our leading cities, can be built from funds so saved without becoming a burden. *Waste prevention* and *water purification* are now the order of the day, and they ought to go hand in hand.

In New York City a recent report by Mr. James H. Fuertes, C.E., places the waste and unaccounted for loss at 43% of the total supply. In Chicago the probable waste is estimated at over 50% of the pumpage, and costly extensions will be needed continually for tunnels and pumping plants alone if the present wasteful conditions go on, whereas, if means are taken to control these losses, this great outlay may be avoided, and a still greater saving made in extensions to the distribution system; for this doubling of the consumption through waste increases the loss of pressure by friction threefold. The great cost of re-enforcing Chicago's $16,000,000 pipe system does not need to be enlarged upon, but it illustrates the importance of effective waste restriction in our cities.

When in our search for waste we analyze the daily consumption of cities or of districts we meet the difficult question as to what is a fair and reasonable supply, but, strictly speaking, there can be no such thing as a standard per capita consumption by which cities my be compared one with another. Much of the controversy regarding an adequate water supply arises from lack of knowledge of special requirements. For instance, it is folly to compare statistics of total per capita consumption without first separating trade and public uses from ordinary domestic demands. Then again the population per mile of main, the amount of lawn sprinklng per capita, and, above all, the relative luxury and personal habits of the several classes constituting the population of a city must be considered.

As an illustration, the city of Buffalo, with a total use per capita of over three hundred gallons, has a metered consumption for trade purposes alone of forty-six gallons per capita, more than the entire supply of Fall River. Evidently such statistics should

not be compared when cities may differ so widely in the trade use of water.

There is, however, ample opportunity for a study of definite and carefully classified uses, such as that made for the Metropolitan Water District (Boston) by Mr. Dexter Brackett, C.E., in which he found by actual measurement:

Domestic use	25.0	gallons per capita daily.
Manufacturing and trade use	23.5	" " " "
Public use	7.0	" " " "
Total	55.5	" " " "

or less than sixty gallons daily for each man, woman and child. Whereas the Metropolitan District actually received about 122 gallons per capita daily.

In other cities we have a reported total consumption per capita ranging from that in

Buffalo	over 300
Pittsburg and Philadelphia	over 200
New York, Chicago, St. Louis and Boston	from 130 to 160
Providence, Worcester, Fall River and Milwaukee	40 to 80

Abroad one finds such cities as London, Liverpool, Manchester, Glasgow, etc., reporting from thirty to sixty gallons. But there we find a policy of waste restriction has been highly developed.

In this wide range of supply to American cities the reported figures are liable to be in error from an unsuspected slippage in the pumps. One of the first discoveries to the credit of the pitometer was in a city of about 125,000 population, which had been reporting 33% more water than was actually leaving the pumps, and since that illuminating experience, pitometer tests show that leaky pumps are the rule rather than the exception, with losses from 25% to 50% by no means unheard of even in engines of the highest type and largest size. For example tests made last year in Philadelphia for Major Cassius E. Gillette, then Chief Engineer of the Filtration Bureau, revealed an average loss from all the pumps of about 25%, which should of course be deducted from the per capita consumption as ordinarily reported for that city.

A wide variation in per capita consumption is due, as has been

shown, to trade use, which will vary as cities are more or less devoted to manufacture.

Public uses, while but a comparatively small part of the total consumption, include the supply to public buildings, schools and hospitals. Street sprinkling, sewer flushing, and fire extinguishing call for attention when reducing the supply to a per capita standard.

Domestic consumption varies, as already stated, according to the habits of the people, and upon this point we are able to form a fairly well-based opinion as to what constitutes a reasonable allowance. For example, in Worcester, Mass., the total domestic use per capita, as shown by meter, is only 16.8 gallons, varying from twelve gallons in the cheaper houses to twenty-three gallons in the best residence streets.

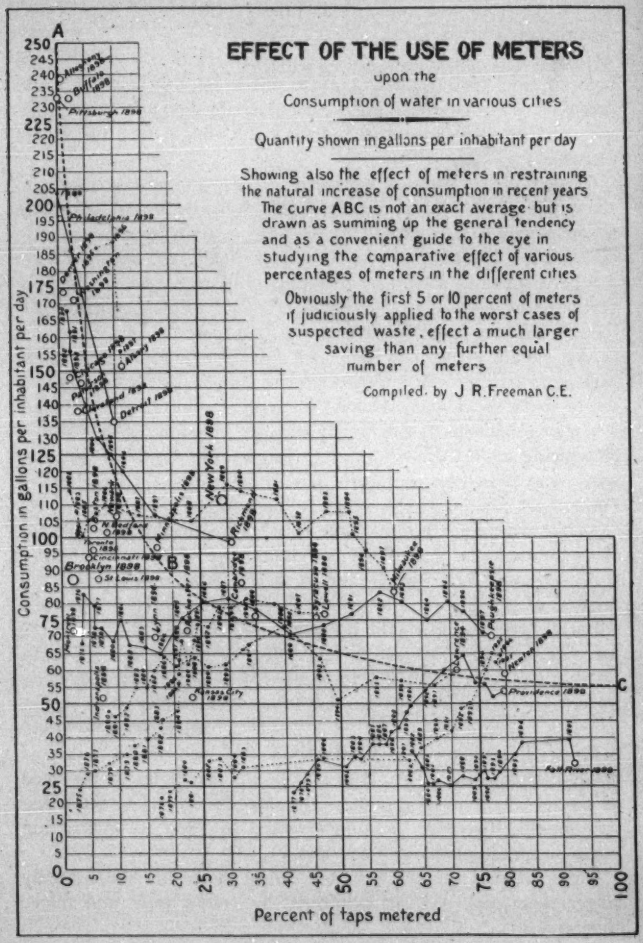
We should remember that such figures are for actual house requirements by meter measurements, and take no account of waste in the service pipe beyond the meter or in the street mains.

An examination of the hourly records of pumpage in cities is convincing as to the existence of waste. The notable feature of such records is that the rate is usually high, even at the dead of night.

While we cannot judge of the relative wastefulness in various cities by a comparison of the per capita consumption, we find in reviewing statistics that the use of meters is attended with a reduction of waste. An interesting diagram first prepared by Mr. John R. Freeman, gives the use per capita of many cities and the percentage of taps metered in each. No better argument for the judicious use of meters should be needed. The effect of placing meters on about 40% of the consumers, including the largest, seems to indicate that a further addition of meters does not yield a proportionate saving. Evidently losses beyond the reach of house meters come in at about this point, and point to the need of special waste investigation. The introduction of a meter system should, therefore, be supplemented by tests for restricting losses in street mains and services.

Leaks beyond the reach of the house meter are undoubtedly larger than supposed, as evidenced by recent tests and meter comparisons.

In a number of cities having practically every tap metered, there is a discrepancy of from 30% to 50% between the total


EFFECT OF THE USE OF METERS
upon the
Consumption of water in various cities
Quantity shown in gallons per inhabitant per day
Showing also the effect of meters in restraining the natural increase of consumption in recent years
The curve ABC is not an exact average but is drawn as summing up the general tendency and as a convenient guide to the eye in studying the comparative effect of various percentages of meters in the different cities
Obviously the first 5 or 10 percent of meters if judiciously applied to the worst cases of suspected waste, effect a much larger saving than any further equal number of meters
Compiled by J R Freeman C.E.
Consumption in gallons per inhabitant per day
Percent of taps metered
A
B
C

pumpage and the total meter registration. This unmistakable loss often remains after allowing for unmetered public uses, fires, and for slip pumps. Leaky, broken, and abandoned service pipes are responsible for much waste, which, because of a porous soil, may not give warning at the surface.

Electrolysis has often been the cause of deterioration of city mains and services and should be carefully studied.

All of the reported pumpage does not reach the main because of what is known as "slip," and "station use" at the pumps. It is customary to make only very small correction for this loss and, in fact, the statistics of most cities are based upon the full amount of water displaced by the pump plungers, the almost universal method being to multiply the recorded strokes of each engine by the theoretical number of gallons displaced per stroke. The only merit of this method lies in its simplicity. That it is liable to gross error has been found on many occasions when the actual discharge from a pump has been measured and compared with the counter record.

This loss should always be determined and deducted from the reported supply to a city, for evidently slip at the pumps is not only misleading, but requires the same engine capacity, steam, and fuel as though the full plunger displacement were discharged into the mains.

DISCUSSION.

PROFESSOR EASBY.—Please explain more fully how you insure accuracy by your method of gauging the flow in a pipe.

MR. COLE.—In the first place, the absolute velocity at the orifices as indicated by the corresponding U-tube deflection has been carefully calibrated in a long open trough by means of loaded floats made to run over a measured course. These floats were timed by electrical contact made automatically at each end of the measured course and recorded by chronograph. In our experiments the trough was of wrought-iron, in the form of an open semi-circular conduit forty feet in length. The measured course was laid out some distance below the head of the trough at a point where the depth of flow seemed to be uniform. The whole affair was hung from a supporting I-beam so as to be adjustable to various slopes. Our pitometers were introduced through 1″

taps placed vertically beneath the trough, the orifices rising to within $\frac{1}{2}''$ of the water surface.

A direct comparison between velocity as determined by the floats and chronograph was thus made with the corresponding U-tube deflection and the plotting of a large number of such comparison tests gave us a calibration curve which when compared with the theoretical flow gave us the value of c equal to .80 in our formula :—

$$V = c\sqrt{2gh}.$$

Thus when gauging the flow in a pipe, we are able to plot the actual velocity at various points in the cross-section by "traversing" two diameters inch by inch from side to side. The orifices ought to remain at each point long enough to give several readings of velocity, the mean of which is plotted so that on completing the traverse we have a curve representing the distribution of velocity from side to side in the pipe. Where, as is often the case, the rate of flow is not uniform, it is necessary to return frequently to the center of the pipe to guard against error through a change of rate. It is often convenient to use two instruments, allowing one to remain at the center, while the other is moved from point to point across the pipe. Observations are of course only taken when the center velocity is normal.

The next step is to divide the cross section of the pipe into a series of rings and approximately equal area, multiplying the area of each by the average velocity for that ring as given at four points ninety degrees apart by the two traverse curves. The summation of discharges found for these rings is, of course, the total flow in the pipe, which divided by the whole area of the pipe gives the mean velocity and this in turn when divided by the maximum velocity observed at or near the center of the pipe determines what we call the "pipe coefficient," which commonly varies according to the condition and age of the pipe from .70 to .90. This ratio of mean to center velocity is the characteristic of each pipe location where a gauging is sought and must first be carefully obtained. When once determined, however, it holds good at all velocities at that particular location, and it is only necessary to leave the pitometer orifices at the point of maximum velocity in order to record the mean flow, which, for practical purposes, will always be a fixed percentage of the maximum. A scale is prepared for each pipe based upon

the computed coefficient. By means of this scale the rate of discharge in million gallons per twenty-four hours for each inch or fraction of an inch of U-tube deflection may be read off from the record.

The final test of the accuracy of a pitometer gauging rests upon the comparison of flow as determined by the above method with that given by a standard weir or measuring tank. A number of tests have been made with weir comparisons in pipes of several sizes up to 72″, and notably at the laboratory of the Worcester Polytechnic Institute, where a very perfect weir receives the flow of a 30″ pipe. We feel justified by our experience in claiming an accuracy of from two to three per cent. in fairly clean pipes when the pitometer is carefully handled.

(Question asked by the Chairman, Mr. Day):

What is the effect of tuberculation upon a pitometer gauging?

MR. COLE.—No attempt is made to accurately measure the flow by our method in a main which is found to be badly corroded. However, the very process of traversing the main as described will reveal the presence of tuberculation, for its effect is to abnormally diminish the velocity near the side of the pipe and thereby reduce the velocity ratio. The net area may often be obtained by the introduction of a caliper which enters the main in the same manner as the pitometer itself and by touching the top and bottom of the pipe will give a fair idea of the net diameter at that point. It is usually quite easy to find a suitable point for gauging the flow to any given district through a pipe comparatively free from corrosion. Ample warning is given by the result of the preliminary traverse, so that an error due to tuberculation is unnecessary. In much district work, especially where flow is obtained by differences between the indications of two instruments, accuracy in the determination of absolute flow is of less importance, as relative values or changes in flow are sought.

MR. BAMBERY, Assistant Engineer of the Gas Improvement Co.—Why is it that one of the pitometer orifices is turned down stream instead of the common form of static pressure?

MR. COLE.—Among many forms of orifice tried these were adopted early in our experimental work because they gave much more reliable indications than the older form. Moreover, the U-tube deflection corresponding to a given velocity was thereby somewhat increased, allowing us to produce a measurable deflection for a velocity somewhat less than $\frac{1}{2}$ foot per second.

MICA DEPOSITS OF WESTERN NORTH CAROLINA.

Although classed as one of the lesser minerals, mica is of considerable importance in the commercial world. Its chief value is in connection with the electrical industry, but it is also used in the manufacture of stoves, lighting apparatus, wall paper, lubricants, paints, boiler covering, fire-proof apparatus, etc. About half of the mica consumed in the United States is of home production; the other half is imported, chiefly from India, though a small amount of "amber" mica comes from Canada. The States contributing the home production in 1905 were, in order of relative rank, North Carolina, Colorado, New Hampshire, Georgia, South Dakota and New Mexico, over two-fifths of the whole being credited to North Carolina.

The mica deposits of western North Carolina have been examined by several investigators working for the State Geological Survey, and with the permission of the State Geologist, a brief paper on the subject, prepared by Mr. Douglas B. Sterrett, appears in Bulletin No. 315 of the United States Geological Survey, "Contributions to Economic Geology, 1906." A detailed report will be published later by the State organization.

Active mica mining has been carried on in North Carolina for the last thirty-eight years, though with varying degrees of energy and success; and the remains of ancient workings, with crude stone tools, around some of the better deposits, suggest early mining by the aborigines or prehistoric people. It is claimed that the earliest mica mining in the State was done in Jackson County on prospects known to Mr. Davis. After a number of Mr. Person had seen a specimen of mica from this county exhibited at the State Fair at Columbus, S. C., by D. D. Davis; and nine years later, when the value of mica was more fully recognized, Mr. Person started operations in Jackson County on prospects known to Mr. Davis. After a number of years' depression, due to low market values at a time when India mica was imported into the country in large quantities, the production is again increased, and old and new mines and prospects are at present interesting many companies and private concerns.

Mr. Sterrett's paper discusses briefly the occurrence, distribution, and origin of the mica-bearing rocks and the minerals associated with the mica, and describes the principal mining properties. Persons who are interested in the subject may obtain a copy of the bulletin by applying to the Director, United States Geological Survey, Washington, D. C.

A NEW METAL called Hydeslite is being produced at a new works, the Hydeslite Metal Company, 2065-2069 Arizona street, Philadelphia. It consists of an amalgamation of various minerals, and when mixed with brass it imparts to it extraordinary strength. While common brass will crumble when exposed to great heat, experiments show that when mixed with hydeslite it will bend or roll hot, neither breaking nor crumbling. Philadelphia manufacturers of goods requiring brass finish are taking so kindly to the new metal that the company is arranging to enlarge greatly the capacity of its plant.—*Iron Age.*

ELECTRICAL SECTION.

(Stated meeting held Thursday, October 10, 1907.)

The Electro-Thermic Production of Iron and Steel.

By Joseph W. Richards, Ph.D.

Professor of Metallurgy in Lehigh University; Professor of Electro-chemistry in the Franklin Institute; Secretary of the American Electrochemical Society.

Why is the metallurgist becoming so largely an electrometallurgist? Because as scientists and industrial men are learning better how to handle electric currents, how best and most efficiently to utilize their decomposing and heating power, they find at their command agencies which can perform what were formerly technical impossibilities, apparatus which can produce at commercially possible costs products hitherto mere chemical curiosities or even ranking among the "chemical unknowns." The mechanical engineer has aided this art by his skill in utilizing water powers, in perfecting gas engines, and in inventing high-efficiency boilers and steam engines. The electrical engineer has contributed still more, by his design and construction of gigantic dynamos, the transmission of large powers to great distances, the conceiving and perfecting of large electrical furnaces. The metallurgist and chemist have utilized these labors of their colleagues to devise new schemes for the extraction of the metals from their ores, new ways of melting metals, new methods of refining metals, new processes for converting cheap raw materials into valuable products of different composition, and finally altogether new products made by novel reactions and adaptable to entirely new and original purposes. There is no need here to specify, in order to prove the proposition; the latest books and the most recent

journals are full of the surprising achievements of the electro-metallurgist and the electrochemist.

In the scientific development of every art, there are always three stages: First, the experimenter, who thinks, imagines, devises, speculates, wonders if this thing will work, wonders if that reaction is possible, and then finally, on a small scale, determines that some reaction or transformation or decomposition of some kind is a possibility which was never proved so to anyone's satisfaction before. This much being gained, the second stage is entered: is the thing capable of being worked on a large scale? This requires the devising of large and often entirely novel apparatus, the overcoming of unforeseen difficulties, the consideration of many new factors. Frequently the apparatus or process finally evolved on a large scale bear little or no resemblance to the original laboratory experiment. Here the metallurgist must plan, calculate, design, and often invent as many novel features as he has difficulties to overcome. The process once working on an industrial scale, the final test of whether it will survive or not will be its ability to command a market for its product, its strength to stand fierce competition from the older processes now fighting for their existence, the capability of the manager to notch down expenses, notch up efficiency, and ever to improve on the quality of the product and its regularity of production.

We may now look at the avenues by which electricity has approached the commercial metallurgy of iron.

Burgess,* of the University of Wisconsin, has shown in his laboratory how iron may be electrolytically refined by a process similar in most of its details to the electro-refining of copper,—until it is turned out practically chemically pure iron, except for a trace of hydrogen, which later is driven off by heating to redness. Here is an electrochemical method of refining worked out to this point: Pure iron, purer than ever before commercially made, can undoubtedly be furnished in any quantity desired at a cost of probably $10 per ton above that of the mild steel used. The Carnegie Institution very generously and very wisely defrayed the cost of these experiments, by a grant of $2500, and it is altogether probable that the exacting demands for pure material by makers of high-class steels of special and very exact composition,

*Transactions of the American Electrochemical Society, Vol. v, 1904.

will lead in the near future to the establishment of a commercial refinery operating Burgess's process, for the production of the highest class of pure commercial iron ever at the command of steel makers. If a rapid tool steel sells at 50 to 75 cents per pound, what is one-half cent per pound on the cost of the raw material if it gives a material to start with which is absolutely pure and therefore of invariable composition?

But the above is not the "electro-thermic" production of iron or steel, and we must back to our subject.

Iron and steel are made, universally, by thermal methods, and the electro-thermic production of these products means simply their production by thermal processes in which the energy of the electric current *as a heating agent* is more or less, or altogether, depended upon to work the process. Pig-iron is made by reducing iron ore by carbon in blast-furnaces; it can also be made by reducing iron ore by carbon in electric furnaces. Steel is made by melting together wrought-iron and cast-iron in a crucible or on the hearth of a Siemens-Martin furnace; the same constituents can be melted together to equally good steel in an induction, arc or resistance electric furnace. Steel is also made by causing iron ore to react on pig-iron, in the open-hearth furnace; the same reaction can be carried out in several types of electric furnaces. Again, iron or steel can be refined in the melted state by oxidizing in the presence of a proper liquid slag; ordinary refining furnaces are limited in the nature of the slag they can use by the limited temperature at their command; electric furnaces can push the refining to much greater limits because of the higher temperature at their command permitting working with highly effective slags ordinarily considered infusible and unuseable. Finally, iron and steel are melted in cupolas, reverberatory furnaces, open-hearth furnaces and crucibles, in order to make castings; they can be melted to liquid material usually of better quality by the use of electric melting furnaces.

I have said that these things *can* be done, meaning by that that they are possible; whether they are commercially possible depends on a dozen of other conditions, which we will duly consider.

The electro-thermic metallurgy of iron has to do with two different problems:

I. The electro-thermic production of Steel.

II. The electro-thermic reduction of Iron Ores.

Speaking chronologically, iron ores were reduced first to wrought-iron, and from wrought-iron steel was made by cementation in red-hot carbon. Afterwards iron ore was reduced in blast-furnaces to pig-iron, which was either used itself in the arts, or served as the basis of production of wrought-iron by the puddling processes, or steel in the crucible.

SIEMENS' EXPERIMENTS.

The development of the electro-thermic production of steel dates from the experiments of Siemens, in 1880, who attempted to use a combined arc-resistance furnace for melting down steel. In this case the material to be melted, held in a plumbago crucible, formed one pole and a water-cooled copper conductor the other pole. The arc between the two furnished the chief resistance and source of heat energy. The material to be melted, by its broken structure, poor contacts between the pieces and with the crucible, formed the smaller part of the resistance. With 1.6 horse-power, 500 grams of steel was melted in fifteen minutes; with 13 horse-power, 2700 grams of wrought-iron in twenty minutes. Since a kilogram of melted steel contains at least 300 calories, and a melted wrought-iron 350 calories, the heat imparted by the current was—

1.6 H.P., 15 minutes $= 300 \times 0.5 = 150$ Calories.
13 H.P., 20 minutes $= 350 \times 2.7 = 945$ Calories.

Since one H.P. hour $= 642$ Calories, the full equivalent of the power used in the two cases was—

1.6 H.P., 15 minutes $= 642 \times 0.4 = 257$ Calories
Thermal efficiency $= \frac{150}{257} = 0.584 = 58.4\ \%$.
13 H.P., 20 minutes $= 642 \times 4.3 = 2761$ Calories
Thermal efficiency $= \frac{945}{2761} = 0.342 = 34.2\ \%$.

While these efficiencies do not appear at first sight high, yet when they are compared with the efficiencies of 3 to 5 per cent. of the heating power of the fuel put into the steel while melting it by coke in a crucible set in a melting-hole, the difference is striking.

The commercial question at once arises: Why was Siemen's method not profitable on a large scale? The answer is to be found in the imperfection of the furnace and not in its inefficiency. The water-cooled copper electrode was dangerous, for it quickly

wore through. The means of regulating the current was not very good, causing great fluctuations in the current passing. The crucible itself became highly heated by the current passing through its walls and lasted but a short time. The steel absorbed both carbon and silicon from the crucible, and copper from the other electrode, and was thus changed in composition. The whole operation and apparatus was conceived on too small a scale. The efficiency, however, so far as the operation went and while it lasted was not bad; power expended at the rate of 585 kilowatt-hours per metric ton of steel melted, while 350 are theoretically necessary.

THE INDUCTION FURNACE.

This was the first to be commercially successful in producing steel. The furnace is a transformer with a secondary of one turn, which latter is a groove filled with the material to be melted. The lining of the furnace—the sides of the groove—were first made of silica, but later of magnesia; the latter was most durable. The induced current generates heat by overcoming the resistance alone of the material to be melted. There is no arc, no electrodes, no movable crucible. The furnace may be placed on trunnions so that it can be poured.

There is only one determination published of the resistivity of molten iron; it is stated by Gin to be 0.0002 Ohm per centimeter cube. The resistance of a circular or other shaped closed groove containing melted iron can therefore be calculated roughly. In an induction furnace the amperes in the secondary of one turn will be those in the primary circuit multiplied by the number of turns, less losses due to magnetic leakage. The energy generated in the iron will be as its resistance multiplied by the square of the amperes passing:

$$Q = RA^2 = \frac{r \times l}{s} A^2.$$

but the weight of iron is:

$$W = \frac{l \times s}{g}.$$

Therefore heating effects per unit of weight of iron

$$\frac{Q}{W} = \frac{g \times A^2}{S^2}.$$

Fig. 1 The 1000 H.P. induction furnace at Voelklingen.

Fig. 2. Top view of same, showing covered groove containing the melted metal.

Fig. 3. View of same during construction.

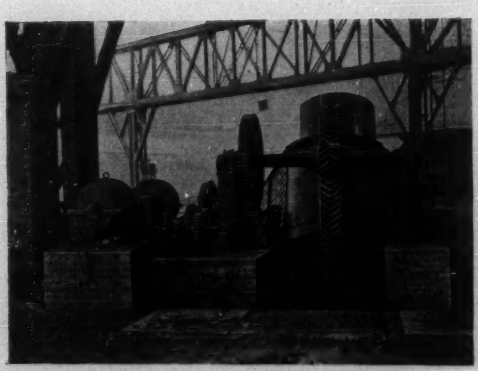


Fig. 4. Back view, showing tilting mechanism.

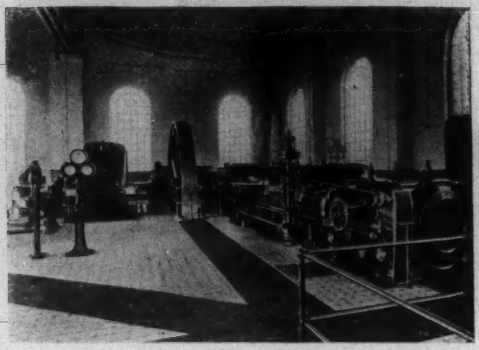


Fig. 5. Power house, showing gas engine.

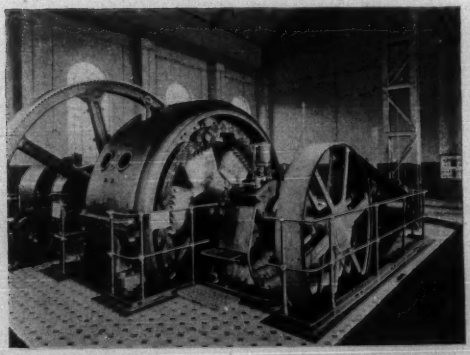


Fig. 6. Alternating current dynamos used.

From this we see that the rate at which energy is delivered to each unit weight of iron varies, for one thing, inversely as the square of the cross-section of the metal in the groove.

The Kjellin furnace first installed at Gysinge, Sweden, in February, 1900, held only 80 kilograms of steel, and with a 78 kw.

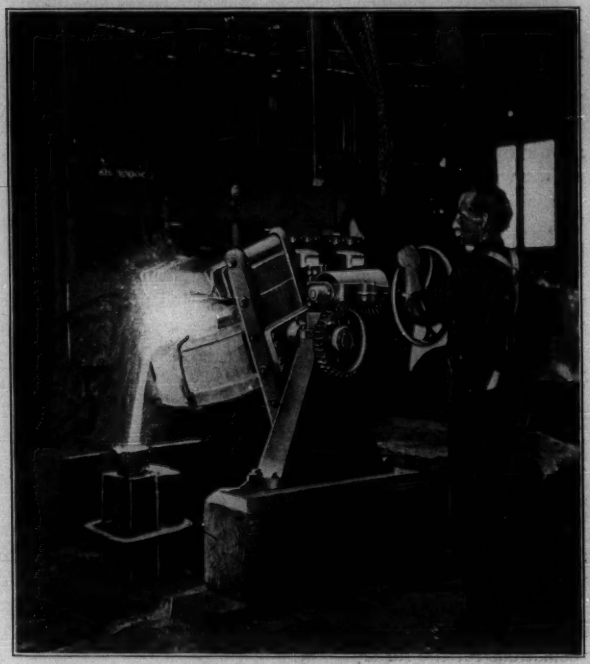


Fig. 7. The Disston furnace.

dynamo produced 270 kg. of steel in twenty-four hours. In November, 1900, a furnace holding 180 kg. was built, and with 58 kw. of electric energy made 600 to 700 kg. of steel per day. Next a furnace holding 1800 kg. of steel was built, run by a 300 H.P. turbine directly driving a dynamo giving 3000 volts on the primary windings of the furnace. This furnace is still in opera-

tion, making 5000 kg. of steel per day. Another furnace has been built and is now running, operated by 165 kw. of current, holding 1350 kg. of steel, and turning out from pig-iron and scrap, charged cold, five tons of steel per day, and when using melted pig-iron six tons.

The American Electric Furnace Co., which builds the Colby and Kjellin electric furnaces in this country, is now supplying steel melters with induction furnaces varying from 25 lbs. of steel capacity, requiring 10 kw., up to 18,500 lbs. capacity, requiring 736 kw. (1000 H.P.). The latter furnace melts 80,000 lbs. of steel in twenty-four hours, with an expenditure of 600 kilowatt-hours per ton of steel if charges are put in cold, and 500 kilowatt-hours per ton with melted pig-iron forming one-third of the charge. A furnace on the same principle to melt charges of 150 tons is now in course of construction at the Roechling Iron Works, Voelklingen, Germany.

Taking the above figures, it will be seen that the induction furnace is attaining a high degree of thermal and metallurgical efficiency. The waste during melting in the induction furnace is only 2.5 per cent., whereas it is some 5 per cent. in open-hearth practice.

PROBLEM I.

Taking the data given above for the output of Kjellin furnaces of increasing sizes, calculate for each the net thermal efficiency.

Solution: One kilogram of melted steel, sufficiently overheated to allow of casting, will contain at least 275 Calories if high carbon steel and 325 Calories if low carbon steel; say 300 Calories for average steel. One kilowatt-hour furnishes 860 large Calories, as its heat equivalent. We have then the following calculations for the furnaces in the order given:

270 kg. melted in 24 hours by 78 kw.

$$\text{Efficiency} = \frac{270 \times 300}{78 \times 24 \times 860} = 0.051 = 5.1\ \%.$$

700 kg. melted in 24 hours by 58 kw.

$$\text{Efficiency} = \frac{700 \times 300}{58 \times 24 \times 860} = 0.18 = 18\ \%.$$

5000 kg. melted in 24 hours by 300 H.P. at the turbine = 224 kw. = 200 kw. effective electrical power at the furnace.

$$\text{Efficiency} = \frac{5000 \times 300}{200 \times 24 \times 860} = 0.36 = 36\ \%.$$

5000 kg. melted in 24 hours by 165 kw.

$$\text{Efficiency} = \frac{5000 \times 300}{165 \times 24 \times 860} = 0.43 = 43\ \%.$$

80,000 lbs. (36,400 kg.) melted per day by 736 kw.

$$\text{Efficiency} = \frac{36,400 \times 300}{736 \times 24 \times 860} = 0.72 = 72\ \%.$$

96,000 lbs. (43,600 kg.) melted per day by 736 kw., if one-third is put in as melted pig-iron, carrying 250 Cal. per kilogram.

$$\text{Efficiency} = \frac{(43,600 \times 300) - (14,500 \times 250)}{136 \times 24 \times 860} = 0.62 = 62\ \%.$$

Charging part of the charge melted is seen to lower the net thermal efficiency, but to increase the output of the furnace. With cheap power, the latter item is of the greatest importance.

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HÉROULT'S FURNACE.

The Héroult tilting electric furnace resembles a tilting open-hearth furnace, with two large electrodes passing through the center of the roof. The electrodes are built up of carbon slabs,

170 centimeters long and 36 centimeters square, at a cost of about twenty cents per kilogram. The hearth is stamped in burnt dolomite, the roof silica brick; the electrodes are protected inside the furnace by water jackets, to prevent their combustion by the air. The furnace can hold 4000 kg. of steel, costs $10,000, and such a one has been in constant operation in La Praz, France, since 1903. The electrodes dip only into the slag, so as not to be dissolved by or carbonize the bath. The current used is 110 volts by 4000 amperes, alternating, and the principal resistance and seat of generation of heat is in the slag between the ends of the carbons and the metal. A disadvantage of this furnace is that it cannot operate without a considerable layer of slag being present.

In such a furnace steel can be made in a variety of ways. Mr.

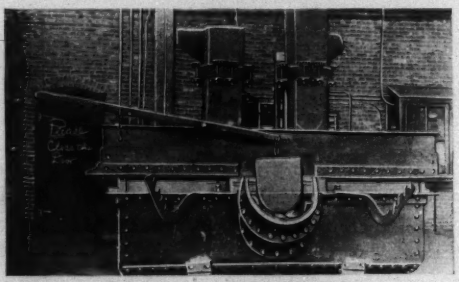

Fig. 8. Front view of a Heroult furnace.

Héroult has preferred to make it from the cheapest raw materials, by processes similar to ordinary open-hearth practice. As is well known, this involves the use of pig-iron, scrap iron or steel and iron ore. The only difference between the two processes is that in the open-hearth furnace there may be considerable oxidation by the gases in the furnace, but in the electric furnace iron-ore must be relied on as the oxidizing agent; it is therefore used to a larger extent than can be used in the open-hearth practice. Considerable lime is added to help form a fusible and basic slag. The oxidation of the impurities consumes time, and therefore the amount of electrical energy required per ton of steel is greater than in the cases cited in the Kjellin induction furnace, where

Fig. 9. Back view of same.

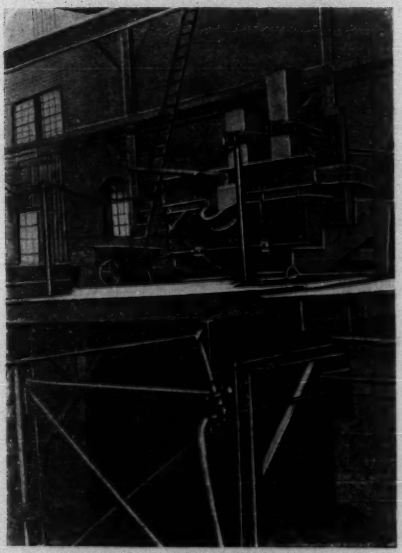

Fig. 10. Showing mounting of a Heroult furnace and casting pit.

high-grade pig-iron and clean scrap were simply melted together in proper proportions.

PROBLEM 2.

A charge composed of—

Miscellaneous steel scrap	5,733 lbs.
Iron ore	430 "
Lime	346 "

was placed in a Héroult furnace, and in five hours twenty minutes was completely melted to soft steel, yielding 5161 lbs. During the melting 1,680 kilowatt-hours of electric energy were used.

Required:—The thermal efficiency of the furnace.

Solution:—The steel scrap is 572 lbs. heavier than the soft steel produced, or 10 per cent. It is very evident that the iron ore used (probably 90% Fe^2O^3) oxidized some of the carbon, manganese, etc., of the scrap, and that the scrap itself was probably oxidized. Miscellaneous scrap may easily be rusted so far as to lose 5 per cent. of its weight while melting down. Calling the soft steel practically pure iron, and the loss of the scrap to represent iron oxide going into the slag, we have as the net result of the melting 5161 lbs. of pure iron and a slag containing silica iron oxide and lime, weighing approximately:

Ferrous oxide	860 lbs.
Silica	43 "
Lime	346 "
	1249

Heat in melted soft steel

$$5161 \times 340 = 1{,}754{,}740 \text{ lb. Cal.}$$

Heat in slag

$$1249 \times 550 = 686{,}950 \text{ " "}$$

$$2{,}441{,}690 \text{ " "}$$

$$= 1{,}109{,}850 \text{ kg. "}$$

Heat value of current used

$$1680 \times 860 = 1{,}444{,}800 \text{ " "}$$

$$\text{Efficiency} = \frac{1{,}109{,}850}{1{,}444{,}800} = 0.77 = 77\%.$$

In working this furnace, with these materials, the slag produced is a necessary part of the operation, and the heat it contains may be taken as usefully applied heat.

These furnaces lend themselves very well to use in connection with melting pig-iron from cupolas or blast furnaces, or melted steel from the Bessemer converter or open-hearth furnace. The electric furnace is fitted to take hot metal, the product of the ordinary steel furnace, and by reason of the higher temperature available to make a slag which will entirely de-phosphorize the metal.

Fig. 11. Showing Heroult furnace alongside an open-hearth furnace, and worked in conjunction therewith.

Such working leaves on the other furnaces the calorific burden of melting the charges and giving them to the electric furnace fully liquid, leaving to the latter merely the task of raising the temperature a little higher and smelting upon them a very basic slag. In such cases, steel corresponding in quality to crucible steel is obtained at but a small cost per ton advance upon that of the Siemens or Bessemer steel from which it is made. The electrically imparted heat is here mostly used to supply radiation losses, and only a minor fraction to increase the temperature of the steel. We cannot, therefore, in justice to the furnace, calculate its thermal efficiency in the manner applied to the case of melting a charge down. In fact, in such cases we can only compare different furnaces on the basis of weight of metal *kept* melted per given time, *e. g.*, per ton of metal kept melted one hour.

ELECTRO-THERMAL REDUCTION.

The most interesting application of electric furnace methods to the metallurgy of iron is in the line of producing cast-iron, pure iron or steel direct from iron-ore. To this may be added the production of ferro-alloys, either by the reduction of other metallic oxides in the presence of iron or mixed with iron ore.

THE FERRO-ALLOY INDUSTRY.

This field has already attained commercial importance in the ferro-alloy line, such as in the manufacture of ferro-manganese, -silicon, -chromium, -tungsten, -vanadium, -boron, -titanium, etc., and a large and steadily increasing industry has been built up. There are probably a dozen electrical ferro-alloy works now in operation, and the industry is flourishing.

The *raison d' être* of this industryis as follows: In the blast furnace, metallic oxides more difficult to reduce than iron oxide are decomposed to varying and often to only trifling degrees. The blast-furnace will easily reduce 99 per cent. of all the iron oxide put into it, losing only 1 per cent. of it in the slag, unreduced. Manganese oxide is not so completely reduced; perhaps 50 to 75 per cent. of it is reduced to manganese and alloys with the iron, forming a product as high as 85 per cent. manganese, while the slag contains the rest, as unreduced Mn.O. Since good manganese ores are scarce and expensive, this loss is annoying and costly. Silica is always present in the blast furnace, and up to 25 per cent. of it may be reduced to silicon, forming a 10 or even 15 per cent. silicon pig, but there the blast furnace reaches its limit; the temperature is not high enough to produce a richer silicon alloy. A low per cent. chromium alloy may be made in a blast furnace, but a great waste of chromium in the slag; a high per cent. chromium alloy cannot thus be made. Tungsten oxides can be reduced to ferro-tungsten in crucibles, but only to a low per cent. tungsten alloy and with much unreduced tungsten in the slag. Titanium, vanadium, boron cannot be reduced to any appreciable extent by carbon and non-electric heating. In all these cases cited, alloys much richer in the non-ferrous metal, and much more complete reduction of the material used, can be obtained in the electric furnace.

Just as electrically-made steel has first found a footing as a competitor of the most expensive kind of steel—crucible steel—so electrical reduction has first found footing in the metallurgy of iron in the production of the most expensive and difficult ferro-alloys.

As an example of the calculations attaching to this branch of the subject, and of methods applicable to all the ferro-alloys, I would cite the production of ferro-silicon, which is attaining constantly increasing commercial and industrial importance.

(*To be concluded.*)

Book Notices.

NEW PUBLICATIONS.

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Sections.

(Abstract of Proceedings.)

Section of Physics and Chemistry.—The Section held a stated meeting on Thursday evening, October 24th, at 8 o'clock, Dr. Edward Goldsmith in the chair. The paper of the evening was presented by Mr. F. P.

Veitch, of the U. S. Department of Agriculture. His subject was: "Wood Turpentine: its Manufacture and Commercial Uses."

Mr. Veitch spoke of the rapid growth of this new industry in the United States, more especially in the Southern and Northwestern States, described the various processes of manufacture, and referred at length to its use in the arts as a substitute for turpentine spirit made from gum resin. The speaker illustrated his remarks by the exhibition of numerous specimens of the product, varnishes made therefrom, and a number of panels of wood varnished with wood turpentine varnish.

The subject was freely discussed and the speaker was voted the thanks of the meeting. Adjourned.

WM. H. WAHL, *Sec'y pro tem.*

MECHANICAL AND ENGINEERING SECTION.—A stated meeting of the Section was held on Thursday evening, October 31st, at 8 o'clock. Present, fourteen members. President Charles Day in the chair.

The Chairman introduced Mr. Edward S. Cole, of New York, who read the paper of the evening on "The Pitometer," an instrument specially adapted for measuring and locating the leakage of water in water mains, from imperfections in pumps, and other sources of waste in the water supply of cities.

The paper was fully illustrated with the aid of lantern pictures. The discussion which followed was participated in by Mr. J. C. Trautwine, Jr., Major Cassius E. Gillette, late Chief of the Bureau of Filtration in Philadelphia, Prof. Easby, of the University of Pennsylvania, Mr. Bamberg, representing the United Gas Improvement Company, the Chairman and others. The speaker was given a vote of thanks, and his paper was referred to the Committee on Publication. Adjourned.

FRANCIS HEAD, *Secretary.*

SECTION OF PHOTOGRAPHY AND MICROSCOPY.—The forty-third general meeting of the Section was held on Thursday, November 7th, at 8 o'clock P.M.

Present, forty-three members and visitors. Dr. Henry Leffmann, President, in the chair.

Mr. Edward T. Wherry, B.S., presented a paper on "Radio-Active Minerals in Pennsylvania," in which he gave an account of his experiments with a number of minerals found principally in Southeastern Pennsylvania, for the purpose of determining the presence or absence of radio-activity in them. These minerals belonged chiefly to the uranium group, and many were found in the neighborhood of Philadelphia. The speaker described his method of operation, stating that he had secured the best results by the use of X-ray plates and an exposure of from three to ten days.

Specimens of these minerals were shown, and the evidence of their radio-active properties was presented in the form of lantern photographs.

The paper was freely discussed and was referred for publication The speaker received a vote of thanks. Adjourned.

M. I. WILBERT, *Secretary.*

MINING AND METALLURGICAL SECTION.—A stated meeting of the Section was held on Thursday evening, November 14th, at 8 o'clock.

Present, thirty-two members. Mr. G. H. Clamer, President, in the chair.

The subject of the paper for the evening was "Recent Advances in the Metallurgy of Zinc," and was presented by Mr. Woolsey McA. Johnson, Metallurgical Engineer, of New York.

The communication was discussed by Mr. C. J. Reed, Mr. Carl Hering, Dr. Edward Goldsmith, and the Chairman. A vote of thanks was passed to the speaker. Adjourned.

WM. H. WAHL, *Sec'y pro tem.*

SECTION OF PHYSICS AND CHEMISTRY.—The Section held a stated meeting on Thursday evening, November 21st, at 8 o'clock. Present, twenty-three members and visitors. Dr. Edward Goldsmith in the chair.

Dr. Allerton S. Cushman, of the U. S. Department of Agriculture, read a communication on "The Corrosion of Iron and Steel," illustrated by numerous experiments and diagrams.

Referred, after some discussion, for publication.

The speaker received a vote of thanks, and the meeting was adjourned.

WM. H. WAHL, *Sec'y pro tem.*

The Franklin Institute

(Proceedings of the stated meeting held Wednesday, November 20th, 1907.)

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, November 20th, 1907.

PRESIDENT WALTON CLARK in the chair.

Present, forty-two members.

The President, on behalf of the Committee on New Building, made a brief statement of the results of the work of the Committee in soliciting subscriptions to this fund. He reported that over two hundred thousand dollars had been pledged by friends of the Institute, which assured the grant of the Franklin Fund to the Institute. The Committee was hopeful, he concluded, that the fund available for the future requirements of the

Institute would be increased by at least one hundred thousand dollars more before the first of April next.

The first communication of the evening was presented by Prof. F. L. Garrison, on "The Production of Gold, and Its Effects on the Cost of Living."

Mr. Strickland L. Kneass followed with an account of some tests made by the late Prof. R. H. Thurston, on "The Wire Cables of the Old Suspension Bridge over the Schuylkill River."

Mr. Romeyn B. Hough, of Lowville, N. Y., who was represented by Mr. Chas. E. Ronaldson, made a communication on "The Characteristics of American Woods," illustrated by a large number of admirable thin sections of typical indigenous woods.

The last subject was referred to the Committee on Science and the Arts.

Prof. Garrison, duly seconded, made some complimentary remarks referring to the zealous and prolonged efforts of Prof. Lewis M. Haupt, in behalf of the establishment of a connected system of internal waterways along the Atlantic Coast, and moved that the Institute reaffirm its previous action in commending this important project. Carried.

Adjourned.

WM. H. WAHL, *Secretary.*